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THE DEPARTMENT OF ENERGY'S FY 1997 BUDGET REQUEST FOR THE OFFICE OF ENERGY RESEARCH (OER)

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The Department of Energy's FY 1997...

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

OF THE

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTH CONGRESS

SECOND SESSION

MAY 8, 1996

[No. 66]

Printed for the use of the Committee on Science

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THE DEPARTMENT OF ENERGY'S FY 1997 BUDGET REQUEST FOR THE OFFICE OF ENERGY RESEARCH (OER)

WEDNESDAY, MAY 8, 1996

U.S. House of Representatives,
Committee on Science,
Subcommittee on Energy and Environment,
Washington, DC.

The Subcommittee met at 10:05 a.m. in Room 2318 of the Rayburn House Office Building, the Honorable Dana Rohrabacher, Chairman of the Subcommittee, presiding.

Chairman Rohrabacher. This hearing of the Energy and Environment Subcommittee will come to order. Today, we will focus on the Department of Energy's Fiscal Year 1997 budget request for the Office of Energy Research.

This office administers the bulk of the DOE's scientific research programs, including Basic Energy Sciences, Biological and Environmental Research, High Energy and Nuclear Physics, and has administrative responsibility for the DOE's multi-program National Laboratories. It also administers the Fusion Energy Program. And, we held a separate hearing on fusion earlier this year.

The Administration's request for Fiscal Year 1997 of $2.548 billion calls for a 2.6 percent increase over current funding. However, most of that increase goes for programs such as fusion and for the European collider program, while Basic Energy Sciences and Biological and Environmental Research are cut.

The Clinton Administration has kept funding for these science programs relatively flat for four years in order to pay for large increases in corporate subsidies, demonstration projects and market development and promotion programs. This Subcommittee expressed its full support for fundamental scientific research last year, and especially in last year's authorization, by funding the Scientific Facilities Initiative. While still meeting our balanced budget commitments, we did fund fully the Scientific Facilities Initiative.

This was the number one priority given this Subcommittee by the Lab Directors in 1995. And, we acted accordingly.

Nevertheless, it appears that this initiative is no longer a high priority for the Department of Energy, since it would take a cut under the Administration's request. We will hear today from the lab directors on how the program is working and whether the request level is sufficient.

There is also a request for a major new commitment for the Large Hadron Collider. This European project would come on top of hundreds of millions of dollars we are spending each year for the construction and operation of domestic colliders and accelerators.

We will hear views on that and other programs from the Director of Energy Research and the lab directors of the DOE's High Energy and Nuclear Physics facilities.

And, Mr. Roemer, I'm sorry to say, is caught in traffic. So, we will hear from him as soon as he arrives, or any other Members when they arrive for the hearing.

But, our first witness today is Dr. Martha Krebs, Director of the Office of Energy Research at the Department of Energy. And, welcome back, Dr. Krebs.

Your full testimony, which is extensive, will be, without objection, placed in the record. And, seeing that there is no one here to object but myself, I'm sure that will be done.

And, I would ask that you summarize, if possible. And, then we will try to get into some of the details with some questions and answers.

Thank you very much. Dr. Krebs, you may move forward.

STATEMENT OF DR. MARTHA A. KREBS, DIRECTOR, OFFICE OF ENERGY RESEARCH, UNITED STATES DEPARTMENT OF ENERGY

Dr. KREBS. Thank you, Mr. Chairman. It's a pleasure to be here again.

And, I am honored to be here representing the programs of the Office of Energy Research. In difficult times, the Office of Energy Research continues to deliver critical elements of the U.S. science base.

In 1996, we are third after the National Institutes of Health and National Science Foundation in contributing to basic science. We are first in contributing to physical facilities, construction and operation, that represent major investments in our national laboratory system.

The DOE user facilities serve some 18,000 to 20,000 users. A large fraction of those are in academia, many supported by the National Institutes of Health, the National Science Foundation and other agencies.

I have three themes today. One is delivering on our commitments. The second is research integration across the Department of Energy programs. And, the third is cutting costs.

In terms of delivering on our commitments, our first commitment is to deliver outstanding science. I believe that we've done that.

The verification of the existence of the top quark was a major achievement of the last year. The 1995 Nobel Prize in physics to Fred Reines and Martin Perl represented both the long-term nature of the investment in basic science, because Fred Reines, for example, did his work in the late 40s and early 50s.

In the case of our user facilities, they not only deliver science of import to the Department of Energy's missions but also support others. And, I would like to bring your attention to this cover from the "Science" magazine of the 1st of March of this year.

This is a picture of something called the Lac Repressor Protein. The function of this protein won a Nobel Prize for two Frenchmen back in 1965. It was a major advance in understanding how, you know, different elements of the genes were controlled, turned on and off.

But, it wasn't until this year that we were able to identify the actual structure of that protein and how, in fact, it interacted with the gene. This could not have been done—in fact, was done with the assistance of the Structural Biology Center at the Argonne National Laboratory and major research to identify this structure was carried out at the National Synchrotron Light Source at Brookhaven National Laboratory.

Our other commitment involves, indeed, these user facilities. The budget for 1997 will continue to make available overall for the user facilities and the Department the level of operation that was provided—initiated in 1996 and the numbers of users have been increased from 1995 from 16.7 thousand about to 18,000 to 20,000 in 1996. And, we think the same number of users will be able to use these facilities in 1997.

We've also delivered new facilities. The Continuous Electron Beam Accelerator Facility at Newport News is on line. We will dedicate it in a couple of weeks.

The Advanced Photon Source at Argonne National Laboratory has come in under budget and on time. We dedicated that last week.

We have facilities in construction. The Relativistic Heavy Ion Collider, that facility is coming along and will be finished with a slight delay primarily due to actions taken by the Appropriations Committee to reduce its budget in 1996.

But, we are also continuing on time and on budget with the Main Injector at Fermilab, the B-Factory at Stanford and the Environmental and Molecular Science Laboratory at Pacific Northwest Laboratory.

We are making progress within High Energy Physics on the Large Hadron Collider negotiations. And, I will be happy to answer questions about that.

Within the Human Genome Program, we are ready to move forward with high throughput sequencing based on the achievements of our scientists in both national laboratories and universities with respect to having developed clone libraries, databases, new reagents that have been commercialized.

In terms of the Fusion Program, although I have testified on that before the budget came out, I would like to say that we are making progress in restructuring that program. We have received a clear and difficult message.

There have been impacts both for individuals and at institutions in terms of reductions at the Princeton Plasma Physics Lab and also other laboratories. We have focused on—we've repositioned the program intellectually as a science focus.

We are investing and see ourselves investing in the future in alternate concepts with small to medium size experiments and continuing international participation but at reduced levels. We have also restructured our science education and our laboratory technology transfer programs.

With respect to research integration, two criticisms that were leveled at the Department by both the Galvin Report and the Yergin Report have been addressed in this budget by strength and collaboration between the Office of Energy Efficiency and Renewable Energy and the Office of Energy Research, particularly in our Materials, Chemistry and Engineering Program, in looking at, you know, new ways to think about and cooperate on our—on these programs.

In the Environmental Management Program, we were told the Office of Energy Research was given responsibility for managing and initiating a program in basic research that supported the Environmental Management Program, about a $50 million program. We went out early this year with a request for applications.

There were 2,200 responses in short proposals. We reviewed them, asked for 700 longer, peer-reviewable proposals. We expect to have grants and awards out to laboratories and universities by the 1st of July.

The key for this program is stable funding and enabling us to use peer review. I think that's what it is going to take it to obtain the kind of long-term interest of the scientific community and a belief that the Department is serious about this program and that Congress is serious about this program.

We are also collaborating with our colleagues in National Security in the areas of high performance computing and neutron science.

As you noted, the Energy Research budget is essentially constant with last year. And, the challenge has been to deliver continued science and service to users.

And, it depends on the laboratories reducing costs and the DOE and the laboratories working together to reduce unnecessary work. The laboratories have committed themselves.

They are reducing their work force. They are working with us to reduce the level of work.

ER has committed itself. We are looking at our own work processes, such as our budget processes and other grant-making processes that affect primarily our university users. We have reduced the oversight in Environment, Health and Safety and our business oversight that previously was, in my opinion, excessive.

And, we believe that we are saving money and reducing the amount of time that people have to spend on these activities. But, I want to say again that I think the laboratories deserve a great deal of credit in this.

It is, of course, easy to do when funding is stable. When it's unstable, it's easy to cut muscle and bone irreversibly. I believe we are getting close to that. FY-97 is a bare bones budget. However, even under these circumstances, we must focus on new opportunities and, in some cases, old challenges.

And, that's why we are moving forward with the negotiation to participate in the Large Hadron Collider. That was—that will be the energy frontier in the first decade of the next century. If we wish to keep our programs and our people in these fields strong, then we need to participate in that.

We also have received advice from the Basic Energy Science Advisory Committee on keeping our eminence, if not preeminence, in neutron science. And, we need to move forward with that.

Fusion has to begin—has to not only deliver the science it has been delivering but has to move forward and promptly, both in the area of basic plasma science and in alternative concept. We do need to move forward with high throughput sequencing in the Genome Program.

And, through all of this, we need to find a way to preserve what is best in our base, which means the people, the facilities and research instrumentation.

In concluding, I would like to say that Energy Research supports some of the most exciting science that this country is involved in. Our researchers and our facilities are at the frontier in critical areas of science.

We make a difference to the DOE missions and to national benefits beyond the Department of Energy. The future of our nations ability to create new technology and maintain economic advance for our grandchildren depends on our investments today in programs like Energy Research.

And, I believe that we, in the Administration, have to work with you, in the Congress, to make sure that we don't lose the people in institutions who make all of this possible. I am prepared to answer questions.

[The prepared statement of Dr. Krebs follows:]

Testimony of Martha A. Krebs,
Director, Office Of Energy Research
United States Department Of Energy
Fiscal Year 1997 Budget Request

House Committee on Science
Subcommittee on Energy and the Environment
May 8, 1996

Mr. Chairman and Members of the Subcommittee, I am pleased to be here today to present the Fiscal Year (FY) 1997 budget request for the programs supported by the Office of Energy Research (ER). These programs are: Basic Energy Sciences, Fusion Energy Sciences, High Energy Physics, Nuclear Physics, Biological and Environmental Research, Computational and Technology Research, Energy Research Analyses, Multiprogram Energy Laboratories-Facilities Support, University and Science Education, and supporting program direction.

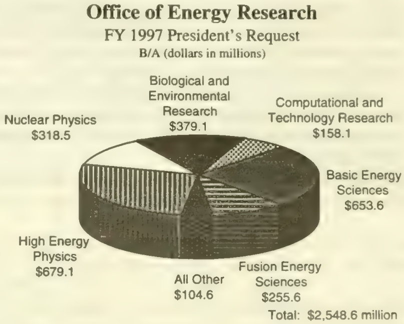
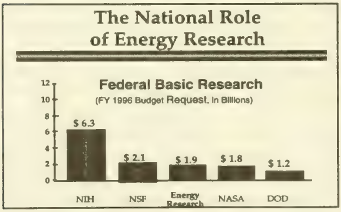


Figure 1

ER's FY 1997 request, which is shown in Figure 1, is earmarked for maintaining the U.S. leadership in performing fundamental science, maintaining scientific facilities, and building the Nation's scientific and technical strength. ER is working with university, industrial and national laboratory research partners to multiply the effectiveness of its activities.

The Office of Energy Research (ER) invests in basic research to enable the Department to succeed in its science and technology intensive missions. Our programs produce scientific and technical knowledge needed to create new and improved energy and environmental technologies and to maintain U.S. scientific leadership in understanding energy and matter. They also provide facilities for research in the physical and life sciences needed by U.S. researchers for forefront research.



DOE's research and scientific facilities help secure the Nation's capability to excel in science and engineering. The Office of Energy Research is committed to replenishing America's pool of scientific talent. We ensure that the national laboratory system supports the Nation's efforts to enhance development of a well-educated, scientifically literate, and diverse work force. ER's programs encourage and seek the contributions of traditionally under represented students and institutions, and small and disadvantaged businesses. Our research at universities, an inherent part of the educational process, helps educate and nurture the next generation of scientists and engineers.

Energy Research's Varied Program

- 90% of U.S. High and Nuclear Energy Physics
- 90% of U.S. Fusion R&D
- World Class Research and User Facilities (accelerators, etc.)
- High Performance Computing
- Bioremediation of Radioactive Mixed Waste
- Human Genome Research and Databases
- Computer Simulation of Nuclear Testing with Defense Programs
- Global Climate Change Research and Databases
- Artificial Intelligence and Robotics

The knowledge, techniques, and instruments developed in the diverse programs of the Office of Energy Research are applied in many areas. These applications include high efficiency energy recovery and use technologies, therapeutic and diagnostic medical applications, and an array of applications in industry and other scientific areas in addition to contributing to the U.S. economic and national defense capabilities.

Highest program priorities in FY 1997 are to sustain the progress made so far in high-energy physics and nuclear physics, to enhance the scientific foundations of the fusion program, and to expand selected programs including optimized the use of the department's scientific and computational facilities. The program will strive to leverage more research funds through increased partnerships.

THE RETURN ON INVESTMENTS IN ENERGY RESEARCH

Basic research supported by ER is increasingly important to America. As reported in the *Wall Street Journal,* "Some of the biggest U.S. Corporations have cut back sharply on research into 'basic science'--the exploration of how nature works at a fundamental level--to pursue short-term goals and to commercialize products more quickly." As 16 chairpersons and CEO's of major U.S. corporations wrote to the Congress, "History has shown that it is federally sponsored research that provides the truly patient capital needed to carry out basic research and create an environment for inspired risk-taking that is essential to technological discovery. " As noted by a member of the Secretary of Energy Advisory Board, DOE cannot succeed in its science and technology intensive national defense, energy, and environmental stewardship missions without excellence in science".

Our research is producing benefits today. ER's current investments are extending the frontiers of knowledge and contributing to addressing many of the Nation's most pressing concerns and priorities.

In 1995, research supported by the Office of Energy Research was cited in four of the five Nobel

Prize awards in physics and chemistry. The award winning physicists discovered the neutrino and the tau lepton, key steps in identifying the fundamental particles in nature. Our chemistry award winners found the effect of freons on the ozone layer in the Earth's atmosphere and the effect of humankind on the environment.

ER research to improve productivity of its high speed computing and communication network (ESNet) pointed the way to technology that can accelerate growth of the information highway by doubling data transmission rates over telephone lines. Other ER supported scientists unveiled a new "warmer" superconductor using a new metal and ceramic tape may be the key to rapid and widespread use of these materials for revolutionary energy savings technologies. In the human health area, our human genome research uncovered the genes thought responsible for certain breast and colon cancers. After a decade of intensive international searching, physicists working at an ER laboratory found the elusive atomic particle -- the quark -- needed to round out our current understanding of the constituents of all matter.

Recent Energy Research Achievements

- **Shared Nobel Prizes In:**
  - **1994 Physics**
  - **1995 Physics and Chemistry**
- **Top Quark Production at Fermilab**
- **World Record In Tokamak Fusion Test Reactor**
- **First Beam in Advanced Photon Source**
- **Human Genome Program - 1996**
  - **Completed Maps of Two Human Chromosomes**

Soon to be the world's brightest sources of hard x-rays, ER's Advanced Photon Source is a beacon for crystallographers, solid-state physicists, structural biologists, and materials scientists to look inside and understand the structure of materials and important molecules. ER researchers in Virginia in 1995 started the first experiments at the Continuous Electron Beam Accelerator Facility. The Tevatron accelerator at Fermilab set a world record for particle beam luminosity. We completed the Radioactive Ion Beam Facility at Oak Ridge National Laboratory that allows scientists to learn the properties of unstable nuclei encountered in astrophysics.

Each year, *R&D Magazine* presents awards to inventions with exceptional industrial promise. In 1995, *R&D Magazine* recognized inventions engendered by ER-supported basic research with seven R&D-100 Awards. The 1995 award-winning technologies will aid in soil cleaning, ultrasonic imaging, and emissions monitoring. On another front, weather researchers and analysts world-wide are eager to see what surprises come out of ER sponsored Greenhouse simulations that more realistically model the effects of absorbent clouds.

PROGRAM GOALS AND STRATEGIES

Consistent with the Department's Strategic Plan, ER has identified five goals that sustain our longstanding traditions of emphasizing scientific excellence and working in partnership with other organizations dedicated to advancing energy and supporting science. Reaching them will help provide America with the range of energy and policy options it needs for future prosperity. The goals are:

- Enable the United States to maintain a position of world leadership in science, mathematics, and engineering needed to enhance energy productivity and ensure reliable energy services while preserving human and environmental health and safety.
- Build and operate the best and most advanced scientific research facilities and infrastructure to advance the frontiers of science.
- Ensure that ER's programs are of high quality, highly productive, and that they are widely known, valued, and trusted.
- Ensure that ER programs protect our workers, the public and the environment during the support of and conduct of research.

Energy Research Goals

- **World leadership in energy science**
- **New insight into the nature of energy and matter**
- **The best research infrastructure for energy science and basic research**
- **High quality, highly productive, widely known, valued, and trusted programs**
- **Protection of our workers, the public and the environment during the support of and conduct of research**

Strategies to support our goals reaffirm our traditional reliance on merit review with peer evaluation of investigator-initiated proposals as we seek new directions for our research programs. These programs will help expand the Nation's human and intellectual resources to ensure that America's capabilities for scientific and technological innovation are constantly replenished. The strategies are:

- *Support science with a purpose.* To warrant Office of Energy Research support, a research project must advance knowledge in key fields and disciplines, further pursuit of departmental missions, or enable timely response to national goals.

- *Provide large scale facilities.* ER supports primarily the large and complex research facilities which help meet the Nations science and technology goals but are too expensive for a single institution or group of institutions to build. We make the facilities available for the best research proposed by university, industrial, and government scientists as decided by peer review.

- *Coordinate research on complex national problems important to DOE missions.* ER programs coordinate and fund multidisciplinary research on complex national problems requiring a long investment horizon to find satisfactory solutions. The problems are found in areas such as advanced materials and processing. The National Laboratories, with their multidisciplinary teams, are special resources for coordinating and performing this research.

- *Assure excellence in research.* We emphasize initiation of proposals by investigators and select the best using peer review. Our program managers measure research quality withscheduled periodic evaluations, including assessment by panels of technical experts. For excellence in the future, we reach out to improve the quality of and access to science, mathematics, and engineering education to replenish America's storehouse of scientific talent.

- *Continuously improve the quality of our administrative processes.* We increase our effectiveness and productivity by improving program management practices and by using performance based contracts with our laboratories. Quality improvement includes leveraging resources through domestic and international partnerships. ER's programs seek out America's excellent scientists, employees, and contractors.

Energy Research Strategies

- Perform science with a purpose
- Coordinate multidisciplinary research on complex national problems
- Provide large scale facilities and technology for doing science
- Catalyze excellence in research
- Continuously improve quality
- Advocate effectively the role and relevance of Energy Research

- *Advocate effectively the role and relevance of the research we support.* We are reaching out more than ever through presentations, newsletters, and the Internet to inform the public about the exciting results of the research we support.

ER managers use a variety of mechanisms to measure program performance and maintain continuing attention to evolving national needs, chief among them peer review. As in other Federal basic research agencies, ER program managers primarily use proposal peer reviews (before work begins as part of the selection process) for research performed by others, usually universities. They primarily use in-progress peer reviews (what is being or has been accomplished after work has begun) for research performed by the Agency's own laboratories. DOE laboratories conduct their own independent peer reviews as a quality assurance measure. It is required by their performance based contracts with the DOE.

Performance measures used to evaluate the ER program are: (1) Quality of the basic science as indicated by expert advisory committees, peer reviews, sustained progress, recognition by the scientific community, and world class research facilities; (2) Relevance to DOE missions and national needs, for example, by supporting energy technology development and joining research efforts with others; (3) Effectiveness and efficiency of construction and operation of research facilities as indicated, for example, by meeting user needs, achieving performance specifications, meeting schedule and cost milestones, and making possible research at the forefront of science; and (4) Good research program management, for example, quality of research planning, meeting budget projections and milestones, and good decisions in managing and redirecting projects.

IMPLEMENTING THE PROGRAM

Through its FY 1997 budget request, ER will continue to seek the most promising and highest quality investments in research and facilities. The projects ER supports annually cover a wide range of DOE mission related disciplines of the sciences and engineering and all levels of education. The research and energy communities have direct input into ER's funding decisions; this year, for example, several thousand researchers and educators will participate in the process of reviewing proposals submitted to the program. Five standing advisory committees --in basic energy sciences, biological and environmental research, high energy physics, nuclear physics, and fusion energy sciences -- provide periodic and invaluable advice on program direction, content, quality and productivity.

PARTNERSHIPS FOR INCREASED PRODUCTIVITY

To leverage the public's investments we are working with university, industrial, and national laboratory research partners to increase the effectiveness of our activities. The most productive R&D efforts are those in which science and engineering work together, concurrently. With the FY 1997 program, we commit ourselves to this model or paradigm for research productivity.

ER programs are important in interagency activities coordinated by the National Science and Technology Council, and promote international cooperation and cost-sharing.
We will do this in the Partnership For A New Generation Of Vehicles (PNGV), in global change research, in human genome R&D, and in R&D for the National Information Infrastructure (NII).

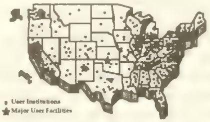
ER programs continue to strengthen science and technology partnerships within the department. Several key areas -- Environmentally Responsive Technologies of the Future, DOE 2000, Industries of the Future, Computational Geoscience and Bioremediation Science -- hold untold opportunities for technological advances to meet the Department's missions. ER program managers continue to strengthen collaborations with the Office of Environmental Management and the Office of Energy Efficiency and Renewable Energy.

In partnership with the Office of Environmental Management, the Basic Energy Sciences and Biological and Environmental Research programs perform fundamental research that addresses problems in environmental management, remediation, and restoration that are intractable without new, fundamental scientific information and technologies. In Partnership with the Office of Energy Efficiency, ER programs perform basic research in support of the partnership for a New Generation of Vehicles. This research helps to bridge an R&D gap between the Department's fundamental research and its other programs.

MAINTAINING THE SCIENCE USER FACILITIES INITIATIVE

Essential to many of the programs of the Office of Energy Research is access to a broad variety of facilities and laboratories. The facilities include large accelerators, experimental detectors, and reactors, high-precision instruments, synchrotrons, massively parallel computers, high-capacity networks, and high-resolution microscopes. Each of the facilities contributes unique research capabilities to the Nation.

ER Scientific User Facilities



The map shows the location of our laboratories and some facilities.

About 18,000 DOE and non DOE sponsored scientists from industry, university and government conduct unique, cutting-edge experiments at the Department's basic research user facilities each year. The light sources alone are used by about 4,000 researchers annually for basic research in such important areas as polymers, alloys, semiconductors, superconductors, magnetic materials and structural biology. In many research areas, U.S. industry relies heavily upon the Department's facilities to conduct experiments that would otherwise be too expensive, or even impossible, to carry out in the United States.

I am particularly proud of this aspect of our program for it not only sets us apart from the other Federal agencies that support science, it ensures that our Nation will maintain its world leadership across a multitude of scientific disciplines. I am committed to supporting the best scientists in the world at our first-rate facilities, to managing these facilities in an efficient, cost-effective way consistent with all matters of environmental compliance, and to measure ourselves continually, as we have in the past, by peer review of our products and our performance.

With the Science User Facilities Initiative started in FY 1996, ER increased access to its basic research facilities. This initiative, affecting 23 user facilities nationwide, increased the number of users at many of our facilities by about 30 percent and supports the President's commitment, articulated in *Science in the National Interest,* to make investment in science and its infrastructure a top priority. We are maintaining support for this initiative in FY 1997. Approximately 20 percent of Initiative funds will be provided directly to user groups through competitively awarded grants.

SUSTAINING HIGH ENERGY AND NUCLEAR PHYSICS

The Department of Energy remains the primary steward of high energy and nuclear physics in the country. Part of this is historical, related to the origins of these programs in the Atomic Energy Commission, but most of it is related today to the fact that the Department sponsored researchers are world leaders in this forefront area of physics, and in the design, construction, and operation of the kinds of facilities that are needed to pursue this research. In particular, scientists supported by our High Energy Physics program in the past year have found the "top quark," rounding out the picture of the physical world at its most fundamental level. Continuing U.S. leadership of this sort over the next several decades will require continued investment in national and international research.

The ER high energy physics program continues its preparations for U.S. participation in the Large Hadron Collider project at CERN. This activity enables the U.S. to participate in new discoveries at the highest energy frontier. We plan to complete the B-factory project at the Stanford Linear Accelerator Center in FY 1998 and the Main Injector project at Fermilab in FY 1999. Both projects are on schedule and within estimated costs. The Main Injector will provide a doubling of intensity for the fixed target program and a fivefold increase in luminosity for collider experiments. This will let us take a closer look at the nature of the top quark. The B-factory will enable scientists to study charge-parity violation, a process that accounts for the complete dominance of matter over antimatter in our universe and, therefore, our very existence.

In the nuclear physics program, construction will continue at Brookhaven National Laboratory on the Relativistic Heavy Ion Collider (RHIC). This facility will provide an unparalleled opportunity to study the subcomponents of nuclei (quarks) as they move freely through hot dense nuclear matter. The Continuous Electron Beam Accelerator Facility (CEBAF) in Newport News, Virginia, began full-scale operation in FY 1996. Designed to probe the quark structure of matter, CEBAF is already generating intense interest from the scientific community. Users from a community of over 1,000 scientists in about 200 research institutions have already scheduled beam time at the facility.

BUILDING A NEW FUSION ENERGY SCIENCES

The fiscal year 1997 budget submission reflects a restructured fusion program, with a change in focus from a narrowly-defined energy technology program (based upon the tokamak concept) to a broadly-based scientific program that emphasizes cost-effectiveness and innovation. The restructured program, proposed in the Fusion Energy Advisory Committee report, *"A Restructured Fusion Energy Sciences Program,"* will explore the critically-important basic science and technology foundations necessary for a future push toward commercially and technologically viable fusion power. The restructured program will pursue energy applications of fusion through its continued involvement in international collaborations. The requested funding level will allow the exploration of previous investments in facilities and personnel and an orderly transition to new priorities, including an academically-based plasma science initiative.

TARGETED RESEARCH INVESTMENTS

Before briefly discussing each of the ER programs I would like to highlight selected areas that receive special attention in the FY 1997 budget request.

DOE 2000 - The FY 1997 request provides initial funding for the joint Energy Research and Defense Programs DOE 2000 Initiative that applies advances from recent high performance computing and communications research to extend the availability and utility of our laboratories and user facilities. The scientific power of the national laboratories will become more accessible to university, industry, and national laboratory researchers. Scientifically important capabilities of the DOE "weapons" laboratories will become accessible for unclassified research from across the United States. Scientists dispersed across the Nation will find it possible to use DOE experimental facilities and work together on problems as easily as if they were in the same building.

Research will proceed in two thrusts. Tools and networks to permit scientists and engineers working at dispersed laboratories to use national laboratory facilities and to collaborate in solving problems will be emphasized first. The second thrust will focus on scientific computation tools, other software, and computer infrastructure to enable computer simulation to be used in place of experiments that are too dangerous, too expensive, or simply inaccessible by other means.

Computational Geoscience, Oil and Gas - Our FY 1997 request provides for continuation of a small and innovative program in computational geosciences. A new multidisciplinary field, computational geosciences uses advanced mathematical and computational approaches, many of them products of nuclear weapons R&D, to characterize and interpret fluid flow underground. The research emphasizes underlying general principles and phenomena. For this reason, it will serve the oil and gas, environmental restoration, geologic disposal of radioactive and hazardous wastes, and geothermal energy mission areas of the Department.

We are excited about this new basic research effort because it opens new avenues in understanding the subsurface behavior of oil, gas, geothermal fluids, liquid wastes and water. This activity capitalizes on the interdisciplinary strengths of the DOE laboratories and it integrates research performed at DOE laboratories and universities for ER and other DOE programs, and research by the oil and gas industries, under common goals. Extensive customer input, gathered with the help of the National Academy of Sciences and others, provides the basis for selection of research areas.

Human Genome - The Department carries out its share of the Human Genome Project (HGP) in full collaboration with the National Institutes of Health and the international community. The ultimate goal of the entire Human Genome Project (HGP) is to decipher all the three billion DNA subunits that are the genetic code within each human cell. Currently only 2 percent of the human DNA sequence is known. In order to complete the task in a timely and cost effective manner, DNA sequencing technologies need improvement.

The Department's genome program is heavily oriented toward technology development which has resulted in a rapid advancement in technologies that promise to significantly increase the speed and decrease the cost of DNA sequencing. For example, improvements in sequencing and automation technologies that could increase DNA sequencing throughput tenfold have entered the pilot production stage. Reliable DNA clones for genome sequencing have also been developed as have new molecular labels that provide stronger, more regular, and more easily detected signals for DNA sequencing. In addition, a newly designed enzyme that greatly improves the quality of DNA sequence data is now commercially available.

An important component of the Department's HGP is the continuing study of ethical, legal and social issues (ELSI) related to the availability and use of genomic information. Among the accomplishments of the ELSI program are: a model genetic privacy law that has been introduced in the legislatures in eight states; a series of workshops on genetics to assist judges in evaluating the relevance of genetic evidence; and high school curriculum units that help students understand both the science and the societal implications of the information coming from the HGP.

During FY 1997, the Department's HGP will place increased emphasis on enhancing automated high-throughput DNA sequencing. In the process of evaluating and implementing these new technologies, an additional 3% of the human genome will be sequenced. A second major goal during FY 1997 will be expanding access to and usefulness of the available genomic information. Programs are being developed that will allow the entire scientific community to contribute to the human genome knowledge base. The available sequence information will be used to assemble a complete physical map of the human genome, that identifies unique DNA marker sequences for the majority of human genes.

Global Change Research - The prediction of global climate change is a key to intelligent decision making on a host of issues relating to the stewardship of the planet. A critical issue among these is energy usage and its effects. The global change program at DOE focuses on research that will enable long-term prediction of climatic effects. This research provides knowledge for informed energy policies. Better information for decision makers means greater assurance that minimum economic and human hardship will result from energy policy decisions in the present and in the future.

Through the ARM program, sites in climatically significant regions are being thoroughly instrumented to provide data critical to improving general circulation models (GCM's) so that these important computational tools can be used to provide reliable predictions of climate change under various scenarios of human activity. The Computer Hardware and Mathematical Models Program (CHAMMP) is providing research to bring many of the GCMs up another notch technically so that advances in parallel processing and other aspects of advancing computer technology are utilized and brought to bear on the prediction problem as quickly as scientific validity permits.

Bioremediation Science - Bioremediation promises a way to significantly reduce the cost and improve the effectiveness of remediation of DOE's contaminated sites. This technique uses living organisms to reduce or eliminate environmental hazards resulting from accumulations of toxic chemicals or other hazardous wastes. Bioremediation has been implemented successfully for degradation of petroleum hydrocarbons and, to a limited extent, degradation of explosives and chlorinated hydrocarbons, as well as for immobilization of toxic trace metals.

The FY 1997 request provides for ER leadership of the Natural and Accelerated Bioremediation Research (NABIR) Program that builds on the expertise of the ER's Biological and Environmental Research program in subsurface biology and genome research. NABIR emphasizes fundamental research on in situ bioremediation of soils and groundwater. Additional knowledge applicable to ex situ waste treatment schemes will be learned and transferred. In FY 1997, ER will expand its exploration of the world of microbial diversity, mapping and sequencing the genomes of microorganisms for possible use in bioremediation.

Environmental Technologies For The Future - In addition ER supports fundamental research needed to assess the potential environmental consequences of human activities on the sustainability of essential environmental systems and resources. Such research builds on BER's tradition of sponsoring fundamental research in the environmental and life sciences, and is motivated by the Office of Energy Research's commitment to supporting the Department's mission to provide technical information and the scientific foundation needed to improve and maintain environmental quality.

These initiatives, from scientific facilities to environmental technologies for the future, account for the increases in the ER budget from FY 1996 to FY 1997. In parallel, the request in several areas decreased from FY 1996 to FY 1997, due to the successful completion of work or because program directions changed. Construction will be completed on two facilities for genome research. Several congressionally mandated projects will be completed. Support for the AMTEX partnership will be transferred to Energy Efficiency and Renewable Energy (EE) DOE.

THE ENERGY RESEARCH PROGRAMS

FY 1996 Appropriation - 2485.2 M - FY 1997 Request - 2548.6 M (Table 1).
ER's budget request of $2,548.6 million for FY 1997 is shown in Table 1.

OFFICE OF ENERGY RESEARCH
FY 1997 PRESIDENT'S REQUEST
B/A
(dollars in thousands)
Table 1

	FY 1995 Conf. Approp.	FY 1996 Conf. Approp.	FY 1997 Cong. Request
Energy Supply R&D			
Basic Energy Sciences	596,727	$654,576	$653,675
Computational and Technology Research	75,778	150,498	158,143
Advanced Neutron Source	12,781	0	0
Fusion Energy Sciences	333,292	227,394	255,600
Biological and Environmental Research	408,245	406,401	379,075
Energy Research Analyses	3,330	3,414	2,000
University and Science Education	61,461	18,900	9,900
Multiprogram Energy Labs-Facilities Support	28,702	34,105	28,885
ER Energy Supply R&D Program Direction	50,967	43,704	42,154
Small Business Innovation Research	68,993	0	0
Small Technology Transfer	3,446	0	0
General Reduction for Use of Prior Year Bal	-19,696	-35,982	0
Total, Energy Supply R&D-Energy Research	1,724,026	1,503,010	1,539,432
General Science and Research			
High Energy Physics	632,163	667,000	679,125
Nuclear Physics	326,776	304,500	318,425
General Science Program Direction	11,400	10,650	11,600
General Reduction for Use of Prior Year Bal	-10	0	0
Total, General Science and Research	970,329	982,150	1,009,150
TOTAL, ENERGY RESEARCH	$2,694,355	$2,485,160	$2,548,582

I will summarize the ER programs by appropriation, namely Energy Supply Research and Development and General Science and Research.

ENERGY SUPPLY RESEARCH AND DEVELOPMENT PROGRAMS

BASIC ENERGY SCIENCES

FY 1996 Appropriation - $654.6 M - FY 1997 Request - $653.6 M (Figure 2)

The Basic Energy Sciences (BES) program is a principal U.S. sponsor of fundamental research in broad areas of materials sciences, chemical sciences, geosciences, biosciences, and engineering sciences. This research underpins the DOE missions in energy and the environment, advances energy related basic science on a broad front, and provides unique national user facilities for the scientific community. The program funds more than 2,400 researchers at 200 institutions nationwide. Over one quarter of BES funds go directly to support research at academic institutions.

The three hallmarks of the Basic Energy Sciences program are excellence, relevance, and stewardship. All BES research programs undergo rigorous peer evaluation through competitive grant proposals, program reviews, and advisory panels. This year, BES researchers were honored with dozens of awards, prizes, and fellowships, including the most prestigious award given in science, the Nobel Prize. Strategic directions are set through working relationships with other DOE programs, research workshops with public and private scientific communities nationwide, and policy directives. As a result, BES has 120 cost-shared Cooperative Research and Development Agreements (CRADAs) with industry, which extend the basic research to applications and development. BES also has hundreds of non-CRADA industrial collaborations, many initiated by industry scientists, which do not involve BES support of the industrial partners.

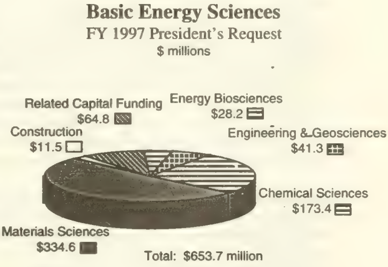


Figure 2

In addition to supporting research performers, BES is also the steward of the major national user facilities for materials sciences, chemical sciences, geosciences, environmental sciences, biological sciences, and medical sciences. BES has overseen the planning, construction, and operation of more than a dozen such facilities, including third generation synchrotron light sources, high flux neutron sources, and specialized facilities for microcharacterization, materials synthesis, combustion research, and ion beam studies. These facilities have an enormous impact on science and technology, ranging from determinations of the structure of superconductors and biological molecules to the development of wear-resistant prostheses, from atomic-scale characterization of environmental samples to elucidation of geological processes, and from the production of unique isotopes for cancer therapy to the development of new medical imaging technologies.

BES user facilities are open to all qualified investigators in academia, industry, and government laboratories, including scientists from about 100 U.S. companies. With the Science User Facilities Initiative, we have substantially increased operating hours and upgraded beamline instrumentation at the synchrotron light sources and the neutron sources.

There were two important milestones at the Advanced Photon Source at Argonne National Laboratory this year. The APS is one of only three third generation, hard x-ray sources worldwide, and it is the only one in the Americas. The first x-rays were observed on the experimental floor on March 26, 1995. Less than one year later, the APS achieved its design specification of 100 milliamperes of electron beam current circulating in the storage ring. The APS will be officially dedicated on May 1st of this year.

Materials Sciences - This subprogram creates new knowledge of materials structures and properties, that is, the scientific foundation necessary to optimize the behavior and performance of materials for clean and efficient energy technologies, and to develop more efficient techniques for waste minimization and environmental remediation. Indeed, *all* energy technologies are materials limited. The performance parameters, economics, environmental acceptability and safety of all energy generation, conversion, transmission, and conservation technologies are limited by the behavior of materials. Materials research is crucial to advanced automotive technologies; the safe and reliable transport, containment and storage of hazardous substances; and the minimization of wastes in the synthesis and processing of commercial materials.

Materials research seeks to understand the synergistic relationship among the synthesis, processing, structure, properties, and behavior of a diverse range of materials. In FY 1997, the subprogram will remain a major supporter of basic research in the synthesis, processing and performance of high temperature superconductors, hard and soft magnetic materials, high temperature alloys and polymers, and of surface science. The budget request will continue basic research in such topics as aqueous and galvanic corrosion, neutron induced irradiation damage, welding and joining, high rate and superplastic metal forming, bulk metallic glasses, solar photovoltaics, high temperature structural ceramics and ceramic matrix composites, solid ceramic electrolytes for batteries and fuel cells, and nondestructive evaluation techniques.

Chemical Sciences - Our chemical sciences research expands knowledge of chemistry and aligned scientific disciplines expected to contribute to new and environmentally responsible energy and industrial processes. Theories and data gotten with this research contribute, directly and indirectly, in such areas as producing fuels and chemicals from coal and biomass, environmental restoration and waste management, electrochemical and photochemical energy production, and the efficient and safe use of energy resources. Contributions come from enabling scientists and engineers to predict the atomic and molecular properties of matter and the chemical interactions of its components.

The FY 1997 budget request provides for basic research on combustion, catalysis, environmental processes, waste management, energy intensive processes and technologies, and advanced vehicular transportation. The FY 1997 request will provide increased research on the molecular level interactions between dissolved materials in aqueous systems and soil type substrate surfaces. Long supported research on the molecular origins of catalysis, which recently led to an improved metallocene based catalyst for polymer production, will continue. In FY 1997, the program will keep seeking a fundamental understanding of combustion and tools to predict the chemistry involved in combustion, which is involved in over 90 percent of our energy processes. The FY 1997 budget request also includes support for continued expansion of the Combustion Research Facility.

Engineering and Geosciences - Our engineering research improves fundamental understanding of systems and processes that underlie current engineering practices in energy technologies and builds the technical and conceptual base for solving future problems. The FY 1997 request provides for energy and environmental related topics such as bioprocessing of fuels and energy related wastes; design techniques to extend the life of energy related structures; characterizing oil, gas, and water flow through porous materials similar to soil and rocks; and the behavior of liquid-gas mixtures, for instance, oil and natural gas in pipelines. Work will also continue on intelligent machines and intelligent controls contributing to increased industrial productivity and improved handling of hazardous waste. The engineering research program also sponsors a total of 36 3-year predoctoral fellowships in integrated manufacturing.

Our geosciences research uses many techniques, such as underground imaging, computer modeling, and experimental simulation, to investigate the origin and space/time development of geologic constituents and their interactions in the outer few kilometers of the earth's crust. Hypotheses and theories are tested with direct sampling, in situ experiments and observations, and with surface based observations and analyses. The FY 1997 budget provides for sustaining experimental and theoretical studies of the interactions of minerals and fluids, for example, oil, gas, geothermal brines, magma-hydrothermal solutions, and water, within the crust. It provides for increased effort for geophysical imaging and fluid flow in reservoirs to advance understanding in areas of critical importance to the energy and environmental mission of the Department.

Energy Biosciences - The Energy Biosciences subprogram addresses the increasing number of new opportunities arising at the interface of biology with other basic energy related sciences such as the biosynthesis of novel materials and the influence of soil organisms on geological processes. The FY 1997 request will provide for the continuance of the subprogram's support of research efforts to advance the enormous potential of modern biotechnologies for energy production and conservation. The program emphasizes research in the microbiological and plant sciences as these understudied areas offer numerous scientific opportunities to dramatically influence environmentally sensible energy production and conservation. Areas of interest include plant productivity, conversion of biomass and other organic materials into fuels and chemicals by microbial systems, and biological systems to replace energy intensive or pollutant producing processes.

Lastly, the Basic Energy Sciences Capital Equipment request for FY 1997, which is essential to the continued success of the program, includes such items as electron microscopes, neutron spectrometers, molecular beam equipment, and computers for equipment control and data analysis.

COMPUTATIONAL AND TECHNOLOGY RESEARCH

FY 1996 Appropriation - $150.5 M, FY 1997 Request - $158.1 M (Figure 3)

The Computational and Technology Research Program (CTR) conducts research in applied mathematical sciences, high performance computing and communications, information infrastructure, advanced energy projects research, and technology research. The subprogram also serves as an advocate within the Department to formulate and coordinate the Department's National Information Infrastructure (NII) initiative, especially to promote economically beneficial energy-related "National Challenges" applications such as energy demand and supply management and to develop the underlying technologies to enable these applications. The Office of Computational and Technology Research manages the SBIR and STTR programs. The program explores advanced energy concepts at an earlier stage of development than departmental energy technology programs. Its technology activities include the cost-shared laboratory Cooperative Research and Development Agreements (CRADAs), technical assistance to small business and the Environmental Technology Partnerships. An effort in Intelligent Energy Processes is an important element in the integrated research program.

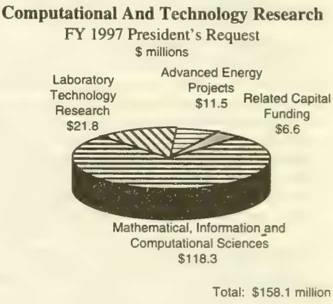


Figure 3

The program, which consists of the following three major subprograms, works closely with other Energy Research and departmental programs.

Mathematical, Information, and Computational Sciences - This subprogram supports a spectrum of activities ranging from fundamental, long-range mathematical and computational research that underpins all of the Department's programs to the management and operation of a leading edge information infrastructure. This subprogram contributes to the multi-agency High Performance Computing and Communications (HPCC) program, and advances all aspects of scientific computation. This program of basic research to technology development includes activities such as High Performance Computing and Communications, the National Information Infrastructure, the Computational Technology program, and the joint Energy Research-Defense Programs DOE 2000 initiative. The driving requirement for the HPCC program is to advance the fundamental concepts and techniques which underpin all energy sciences and development. The HPCC program will substantially expand and accelerate development of a new generation of computing and communications technologies, facilities, applications, and trained personnel.

The net increase in funding from FY 1997 is due to enhanced efforts in National Collaboratories and Advanced Computational Testing and Simulation (ACTS) in support of the DOE 2000 initiative. This is a joint Energy Research - Defense Programs effort to develop and test a common technology base that supports both National Collaboratories and ACTS. Efforts are underway to extend the DOE 2000 initiative to other DOE programs and other agencies as it matures.

National Collaboratories Research - Seeks to develop a set of tools and capabilities that will permit scientists and engineers working at different DOE and other facilities to collaborate on solving problems as easily as if they were in the same building. The program thrust in ACTS and Simulation will produce an integrated set of algorithms, software tools and infrastructure that will enable computer simulation to better complement experiment and theory or to be used in place of experiments when real experiments are too dangerous, expensive, or inaccessible. The efforts in these areas are closely coordinated with related activities supported by Defense Programs.

The request provides funds to support the National Energy Research Supercomputing Center, that will provide research time for about 5,000 scientists in universities, Federal agencies, and U.S. Companies, or the same level as FY 1996. The benefits will flow to researchers from the structural biology, materials sciences, superconductor technology, medical research and technology development, plasma sciences, and environmental and atmospheric research communities. In 1997, the program will start development of applications development in compressible fluid dynamics/combustion, environmental chemistry, and materials sciences. The subprogram will integrate the most critical existing software tools into ACTS framework as part of the DOE 2000 initiative. The request also provides for upgrading ESnet bandwidth services to support high speed Program Integration and ACTS applications as part of the DOE 2000 initiative.

Laboratory Technology Research - The Laboratory Technology Research subprogram links the basic science at ER national laboratories to applied technologies through leveraged collaborations with industries. The program is focused in critical technology research areas, e.g., intelligent manufacturing processes, tailored materials, and sustainable environments, to contribute technological innovations that will stimulate national economic growth, and to increase the return on the government investment in basic science. Research is conducted through peer-reviewed collaborations, including cost-shared Cooperative Research and Development Agreements (CRADAs), personnel exchanges, technology research and maturation projects, technical assistance/consultations to small business, and major government-industry partnerships with multiple partners. Performance measures related to laboratory technology research focus on reduction of technical risk. The quality of research is evaluated through peer review, workshops, and site visits.

The FY 1997 request provides, for example, research on intelligent processes such as sensor-computer-machine control systems that will focus on high risk technological problems for ultimate commercial applications with high payoff. The potential for large payoff is based on the explosive growth in inexpensive computer technologies and the ability to incorporate them into control systems. In FY 1997, this activity will continue support for 90 ongoing multi-year collaboration projects in technology research focus areas at 5 ER multi-program laboratories. Includes increased support for intelligent energy processes and computational technology. While support of Computational Technology projects and technical assistance activities will increase, the subprogram will eliminate support or the AMTEX Partnership.

Advanced Energy Projects - This activity funds research to establish the feasibility of novel, energy-related concepts that span the Department's energy mission and goals. These concepts are usually derived from recent advances in basic research, but require additional research to establish their feasibility. A common theme for each concept is the initial linkage of new, or previously neglected, research results to a practical energy payoff for the Nation. Efforts are typically supported at a level of $300,000 per year for a period of 3 years. Although the funding profile can vary widely among projects in the Advanced Energy Projects (AEP) research portfolio, the 3-year budget period is considered a maximum. A measure of success is demonstrated if the project attains further funding from another source to realize its full potential. Projects are selected from proposals submitted by universities, industrial organizations, non-profit research institutions, and national laboratories. Equal consideration is given to each submission. Funding criteria include scientific merit as judged by peer review.

The FY 1997 request will maintain the subprogram's present level of research effort in the Department's mission areas by supporting strategic research such as a novel, and potentially highly-efficient approach for converting methane into heat and a new magnetic material that can be fabricated with small feature sizes for use as micromotors. Other research will explore a solar-powered technique for converting carbon dioxide to methanol and for synthesizing and characterizing new materials for energy-efficient, optical imaging.

BIOLOGICAL AND ENVIRONMENTAL RESEARCH

FY 1996 Appropriation - $406.4 M, FY 1997 Request - $379.1 M (Figure 4).

The Biological and Environmental Research Program (BER) provides fundamental science to underpin the five business thrusts of the Department's strategic plan. Through its support of peer reviewed research at national laboratories, universities, and private institutions, the program develops the knowledge needed to identify, understand, and anticipate the long-term health and environmental consequences of energy production, development, and use. The goal of the BER program is to develop the information, scientific "know-how," and fundamental science that underpins new technologies used in the pursuit of detailed understanding of the consequences to health and the environment of energy production, development and use.

A new structure has been developed for the Biological and Environmental Research program. The previous structure no longer reflected the program priorities or the ongoing integration across scientific disciplines. Our new structure contains the following subprograms: Life Sciences, Environmental Processes, Environmental Remediation, and Medical Applications and Measurement Science.

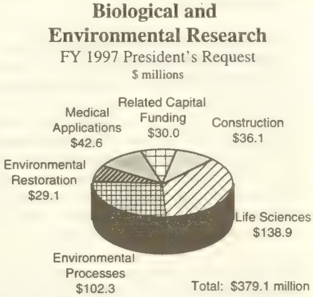


Figure 4

Life Sciences - I have already noted the human genome research in this subprogram. In addition, the FY 1997 request provides for structural biology research to develop and support DOE national user facilities for scientists to learn the molecular structure of important biological molecules, such as enzymes, antibodies, or other proteins. These facilities are critical tools in applications ranging from energy production to environmental remediation. They also provide a means for better understanding the mechanism of action of current drugs and for the design of new drugs to control or treat a variety of diseases.

A major emphasis for FY 1997 is the initiation of a station for structural biology studies at the Los Alamos Neutron Scattering Center at Los Alamos National Laboratory. In addition, a new program in computational structural biology is being initiated to support research to enhance understanding of structure-function relationships in biological macromolecules.

The FY 1997 request provides for research on scientific information and advanced technologies to understand and mitigate the potential health effects from energy activities and cleanup operations. It also provides for research furthering basic scientific understanding of fundamental life processes and biomolecules. In FY 1997, the program will focus on research in support of estimating health risk, understanding molecular structure/function relationships and on applications of biotechnology. Structure/function research integrates information and technologies from genome, structural biology, and cellular/molecular biology research with human health research.

Health risk research for understanding and characterizing the risks to human health from exposures to low levels of radiation and chemicals both at home and at work will receive emphasis in FY 1997. New models for mitigating adverse human health effects by understanding the complex relationships between genes, the proteins they encode, and the biological functions of these proteins also will be emphasized during FY 1997.

Again in FY 1997 biotechnology research will emphasize the application of technologies and resources, especially those developed as part of the human genome program. The budget request provides for a major emphasis on the Microbial Genome to characterize the genomes and proteins of microorganisms with important applications in industry, energy production, and environmental cleanup.

Environmental Processes - The Environmental Process program conducts research on a range of environmental issues, particularly those focused on the consequences of emission of aerosols and trace gases, especially carbon dioxide, from fossil fuel combustion.

The DOE has an integrated observational and modeling program with the goal of predicting climate variability and climate change ten to one hundred years in advance. The CHAMMP program is extending its modeling breakthrough in ocean simulation to develop a coupled atmosphere-ocean model useful for climate prediction. Under the Atmospheric Radiation Measurement (ARM) Program, DOE is investigating the effect of clouds and water vapor on the earth's energy balance. This problem has been cited as the most important barrier to improving the predictions of global change models.

The first instruments for the ARM Tropical Western Pacific Site are being shipped to Manus, Papua-New Guinea. In FY 1997 a second set will be installed on Nauru. The Southern Great Plains Site in Oklahoma and Kansas has been in operation for three years providing critical data to the science community. Mutually supporting efforts in uitraviolet-B radiation, aerosols and mid-latitude stratospheric ozone are ongoing in the Atmospheric Chemistry Program.

In addition to these efforts, DOE supports research on the fundamental mechanisms of the response of terrestrial ecosystems to environmental change to enable prediction of the potential impact of global climate change. The DOE Carbon Research program focuses on the carbon cycle and the impact of energy usage on it. The research provides a scientific basis for assessing the effects of human activities on the earth's climate and for assessing the need for action to mitigate any adverse change. Beyond their mutual scientific support, these programs are coordinated with other agencies through the NSTC's Committee on Environment and Natural Resources.

Environmental Remediation - The research is focused on the understanding of the fundamental physical, chemical, geological, and biological processes that must be marshaled for the development and advancement of new, effective, and efficient processes for the remediation and restoration of the Nation's nuclear weapons production sites. Priorities of this research include bioremediation (which was noted earlier}, the development of the full capabilities of the

Environmental Molecular Sciences Laboratory, and the joint scientific endeavors with the Office of Environmental Management. The subprogram also includes basic research in support of pollution prevention and sustainable technology development.

The FY 1997 requests provides for increased research to improve understanding of the potential of microorganisms for environmental bioremediation. With the establishment of the Environmental Molecular Sciences Laboratory, unified efforts will provide research directions that capitalize on the interdisciplinary nature of the fundamental molecular sciences supporting environmental cleanup. In FY 1997, we anticipate critical contributions to synergistic research directions from additional research on the microbial genome, as discussed above.

Medical Applications and Measurement Science - The medical applications program supports research to develop beneficial applications of nuclear and other energy-related technologies for medical diagnosis and treatment. Program researchers develop applications of radiotracer agents for medical research using recent advances in instrumentation as well as in molecular and structural biology. The research in this activity is conducted in six specific areas: Radioisotope Development, Radiopharmaceuticals, Instrumentation, Clinical Feasibility, Boron Neutron Capture Therapy (BNCT), and Molecular Nuclear Medicine. In FY 1997 the research will continue emphasis on non-invasive diagnostic tools, including imaging technologies such as positron emission tomography.

Our measurement science program focuses on research and development of new measurement technologies to meet the needs of our environmental and life sciences programs and other departmental customers. The FY 1997 request provides for a variety of activities, with particular emphasis on using the advanced technologies developed in the Department's National Laboratories for environmental and biomedical research. The FY 1997 request also provides for dosimetry research devoted to providing fundamental understanding of interactions of radiation with matter needed to improve boron neutron capture therapy (BNCT) and other programs in medical applications and the life sciences.

FUSION ENERGY SCIENCES

FY 1996 Appropriation - $227.4 M, FY 1997 Request - $255.6 M (Figure 5).

The Fusion Energy Sciences Program's new mission is to advance plasma science and fusion science and technology--the knowledge needed for an economically and environmentally attractive fusion energy source. The new program goals are to:

- Advance plasma science
- Develop fusion science, technology and plasma confinement innovations
- Pursue fusion energy science and technology as a partner in the international effort.

The research program is changing significantly in response to the new mission and goals.

Managing the transition of this program to a world-class fusion energy sciences program will be one of the Department's highest priorities in the coming year. While the broad outlines of the program are clear, many important decisions remain. The Department is seeking the best scientific advice available in making these decisions, and it will rely heavily on the outcome of reviews now being conducted by the Fusion Energy Sciences Advisory Committee, to build community consensus around these decisions.

The Department's new fusion energy sciences program for fiscal year 1997 will include:

A Plasma Science Initiative - We will significantly increase funding for basic plasma science, beginning in fiscal year 1997. This initiative will broaden the academic base in the field through outreach to institutions not now involved in plasma science and will include a Plasma Science Young Investigator Award program. Over the next five years, fusion program funding for basic plasma science is projected to grow to approximately $10 million. This initiative will be coordinated with other agencies funding plasma science, such as the National Aeronautics and Space Administration and the National Science Foundation.

A Significantly Increased Emphasis On Alternative Concepts - We will evaluate proposals to identify one or two small alternative concept experiments for construction. One that has already been favorably reviewed is the National Spherical Tokamak Experiment proposed by Oak Ridge National Laboratory, Princeton Plasma Physics Laboratory, and the University of Washington to be built at Princeton Plasma Physics Laboratory. We will also continue our program of cooperation on large alternative experiments in Japan and Europe. We are asking the Fusion Energy Advisory Committee to recommend an overall strategy for conducting an alternative concepts research program in the United States, by this summer.

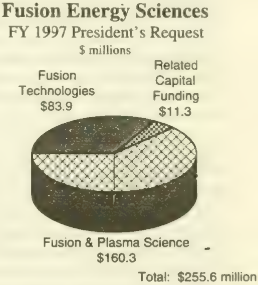


Figure 5

An Increase In Our Fusion Science Knowledge Base - We will use existing major facilities to develop innovative improvements for the Tokamak, construction of a limited number of innovative small experiments funded within an essentially flat budget, and an increased program of research in basic plasma science. Again, Fusion Energy Advisory Committee will recommend priorities among the research efforts that can be addressed using our facilities.

A Shut Down Of TFTR In Either 1997 Or 1998 - The TFTR, as the only tokamak now operating with deuterium-tritium fuel, offers the promise of unique advances in fusion physics. By early 1997 we will have evaluated TFTR's work-in-progress with the assistance of the Fusion

Energy Advisory Committee and will either begin facility shutdown in fiscal year 1997, or will complete a focused experimental program leading to termination in fiscal year 1998. After TFTR shutdown, the Laboratory will continue to be a center of excellence in fusion and plasma science, with strong capabilities in theory and modeling, in diagnostics and instrumentation, and in experimental fusion science, although at a smaller scale and with an even greater emphasis on innovation than in the past.

A Leveraging Of Program Resources Through International Collaboration - We will continue to leverage our resources through international collaboration, which is an integral part of every facet of the fusion program. We will also remain an active participant in the International Thermonuclear Experimental Reactor (ITER) Engineering Design Activities (EDA), through completion in July 1998. The ITER is the only facility presently planned that will permit the study of the physics of long-pulse ignited plasmas, a key area of fusion science. Failure to fulfill our commitment to our international partners would damage our credibility as an international partner and specifically limit our access to facilities constructed by the much larger Japanese and European fusion programs. The Department is beginning a dialogue with other agencies and the Congress on whether or not to enter into informal, noncommittal discussions with the ITER partners on future U.S. participation in ITER construction and experimentation at some modest level.

A Changed But Continuing Role For The Princeton Plasma Physics Laboratory - Even though we will shut down TFTR after exploiting its scientific capabilities, we will maintain the technical infrastructure developed through decades of investment at the Laboratory to provide the core competencies required for national leadership and international collaboration in fusion research.

Changed Program Governance - The Office of Fusion Energy Sciences will be reduced in size and reorganized. The Fusion Energy Advisory Committee will be renamed the Fusion Energy Sciences Advisory Committee, and its membership changed to reflect the scientific nature of the program. The Fusion Energy Sciences Advisory Committee will have a continuing Science Subcommittee that will play a role in providing scientific information to the Fusion Energy Sciences Advisory Committee to aid in priority setting, and will serve as the focus of scientific leadership and consensus building within the fusion community. Peer review will be used for the evaluation of research proposals, assessment of progress and quality of work, and for initiating or terminating facilities, projects, and research programs or groups.

UNIVERSITY AND SCIENCE EDUCATION PROGRAM

FY 1996 Appropriation - $18.9 M, FY 1997 Request - $19.9 M (Figure 6).

The University and Science Education (USE) Program ensures that the Department effectively utilizes and leverages the resources of the laboratory system to support DOE's university and science education mission. USE provides centralized institutional support for DOE's education

University and Science Education

FY 1997 President's Request

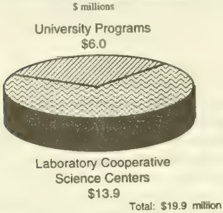


Figure 6

efforts which provide summer and semester hands-on research experiences for students and faculty at the laboratories, supports the Departmental role in the national effort to improve science education for all students, increasing the diversity of the workforce and minimizing department-wide administrative cost.

In FY 1997, USE plans to support: (1) undergraduate and graduate participants in the Laboratory Cooperative Education program; (2) coordination with other DOE programs and improved integration of science education activities; (3) high priority Administration and Congressional science education and diversity programs; (4) a developmental award program for faculty and students from primarily undergraduate institutions and minority institutions that stimulates collaboration with DOE scientists and enhances faculty grant competitiveness; and (5) partnering with National Science Foundation in support of its Minority Institutes of Excellence program to enhance coordination and effectiveness of support for undergraduate programs at HBCUs and coordination with other federal, state, and local agencies.

The FY 1997 request will enable DOE to provide a healthy base program focused on longer term research assignments of undergraduates, graduate students, faculty and post doctoral research appointments at DOE laboratories; and a level of science education institutional support that allows DOE to optimize student and faculty internships and collaborative involvement in DOE research. This approach is consistent with Congressional guidance, supports the Administration's science education goals, and will result in increased efficiency in carrying out the restructured science education program in close collaboration with DOE programs and other agencies, such as the National Science Foundation.

MULTI PROGRAM ENERGY LABORATORIES - FACILITIES SUPPORT

FY 1996 Appropriation - $34.1 M, FY 1997 Request - $28.9 M (Figure 8).

The Multiprogram Energy Laboratories-Facilities Support (MEL-FS) program addresses the general purpose infrastructure needs at the five multiprogram ER laboratories. The five multiprogram energy laboratories are: Argonne National Laboratory-East, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory. These laboratories have an average age of 30 years and have an estimated replacement value of over $10 billion.

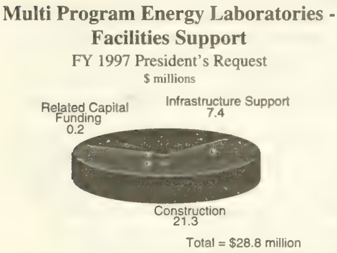


Figure 7

Fulfillment of the science and technology goals and objectives identified in the Department's Strategic Plan depends heavily on the existence and operating efficiency of these multiprogram laboratories. However, much of the infrastructure of these laboratories is old, deteriorating, and obsolete and needs improvement to comply fully with the environment, safety and health requirements in effect today and to meet operational needs.

The MEL-FS program is designed to preserve the government's investment in infrastructure and to maintain infrastructure integrity in a reasonable and economic manner at these laboratories. To achieve this, the program is divided into three activities: Construction, Related Capital Funding, and Infrastructure Support. These activities help to ensure that the infrastructure of the laboratories is adequate to support the Department's missions now and into the future. The FY 1997 budget request for MEL-FS is $28.9 million.

The Construction activity supports refurbishment and replacement of inadequate general purpose facilities and infrastructure. It also supports construction activities associated with necessary site-wide Environment, Safety & Health (ES&H) actions. This includes construction on general purpose buildings, utility systems, roads and other structures. The FY 1997 request for Construction is $21.260 million. This funding allows continuation of nine ongoing line-item projects and no new construction starts in FY 1997.

The Infrastructure Support activity supports ES&H activities necessary to attain compliance with applicable federal, state, local and Departmental ES&H Requirements as identified and prioritized in the DOE ES&H Management Plan. It also includes $0.5 million for Inactive and Surplus Facilities activities and $0.5 million for Improved Planning Systems. These activities provide for cleanup, removal, or preparation for transfer of facilities to DOE's Office of Environmental Management for decontamination and decommissioning and improve facilities and project planning processes, respectively. The total FY 1997 Infrastructure Support request is $7.4 million.

ENERGY RESEARCH ANALYSIS

FY 1996 Appropriation - $3.4 M, FY 1997 Request - $2.0 M

The mission of the Energy Research Analyses program is to conduct technical assessments of the Department's civilian research and development programs and to provide direction to future research and development activities. During the past year, senior research managers within the Department, seeking to enhance the quality of their programs, have requested comprehensive project-by-project evaluations of research programs in solar photochemistry and fossil energy advanced research. Highly specific findings from these reviews provided managers with the authoritative information they needed to modify and improve their programs. Energy Research Analyses also conducted science policy analyses, and developed basic science strategic plans.

The FY 1996 budget request will provide funding for peer reviews of approximately 200 projects in Energy Research, Fossil Energy, and Energy Efficiency to continue to improve the quality and relevance of DOE research and development. In FY 1997, this activity will update and improve the Energy Research Strategic Plan to establish a new vision and mission, and to get maximum research value from the realigned Office of Energy Research. Other activities will include evaluation of critical planning and policy issues of DOE science and technology using expert groups at the National Academy of Sciences, the JASON group, etc., as appropriate.

ENERGY RESEARCH - ENERGY SUPPLY PROGRAM DIRECTION

FY 1996 Appropriation - $43.7 M, FY 1997 Request - $42.2 M

This new program has been established in response to direction from the Congress that within each appropriation, each organization should have only one program direction decision unit for Federal staffing resources and related costs. Program Direction provides the Federal staffing resources and associated costs required to provide overall direction and execution of Office of Energy Research program and advisory responsibilities. Energy Research-Energy Supply Program Direction supports staff in the Basic Energy Sciences, Fusion Energy Sciences, Biological and Environmental Research, Computational and Technology Research, University and Science Education, Multiprogram Energy Laboratories-Facilities Support and Energy Research Analysis programs, including management and technical support staff.

This program also supports staff at the Chicago and Oakland Operations Offices directly involved in program execution, and ER resources at the Environmental Measurements Laboratory. Staff includes scientific and technical personnel and program management support in the areas of budget and finance, general administration, grants and contracts, information resource management, policy review and coordination, infrastructure management and construction management. In addition, beginning in FY 1997, program organizations are contributing to a Working Capital Fund to cover the costs of centrally provided goods and services such as supplies, housing, utilities, etc., which previously were budgeted in Departmental Administration.

GENERAL SCIENCE AND RESEARCH

HIGH ENERGY PHYSICS

FY 1996 Appropriation - $667.0 M, FY 1997 Request - $679.1 M (Figure 8).

The Department of Energy provides over 90 percent of the Federal support for the Nation's high energy physics (also called elementary particle physics) research. High energy physics research seeks to understand the nature of matter and energy at the most fundamental level, as well as the basic forces which govern all processes in nature. It requires accelerators and detectors utilizing state-of-the-art technologies in many areas, including fast electronics, high speed computing, superconducting magnets, and high power radio-frequency devices.

In these areas, high energy physics research has led to many developments with practical applications in the civilian marketplace. High energy physics technology research continues to make major contributions to accelerator technology and develops technical expertise which supports widespread accelerator utilization in other scientific disciplines and industrial processes such as synchrotron light sources and medical diagnostics and treatment.

This program provides the basis for an excellent education for the brightest young scientific minds, so necessary for the program to continue research at the intellectual frontier. Experimental and theoretical researchers from more than 100 universities conduct about three-fourths of the research, with the remainder being done by staff at the national laboratories. This combination of highly skilled scientists and engineers from the universities and our national laboratories contribute significantly to the transfer of technology to other fields.

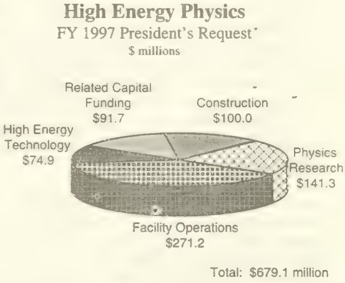


Figure 8

Progress in high energy physics research depends on forefront experimental capabilities, effective use of specialized facilities, and the availability of new and upgraded facilities designed to take advantage of new technologies and research opportunities. The Department of Energy supports three major high energy physics accelerator centers. Each provides unique capabilities and is operated as a national facility available to qualified experimenters around the Nation and abroad on the basis of the scientific merit of their research proposals. Approximately 2,000 U.S. scientists and 200-300 foreign scientists work at these facilities at any given time.

At the Fermi National Accelerator Laboratory (Fermilab), Tevatron, the world's highest energy superconducting accelerator provides both fixed target and colliding beam research programs. The colliding beam research program benefits from having two major detector facilities, the Collider Detector at Fermilab (CDF) and the D-Zero Detector, which complement each other in their differing technical capabilities. In March 1995 the CDF and D-Zero collaborations jointly announced the discovery of the long-sought Top Quark, the last of the six predicted by the Standard Model. In FY 1997 the Tevatron is expected to operate for 29 weeks, continuing the fixed target run begun in FY 1996.

Construction of the Fermilab Main Injector project, to be completed in FY 1999, continues on schedule and within budget. By providing a fivefold increase in collider luminosity, and a doubling of intensity for the fixed target program, this project will greatly enhance the physics capabilities of the Tevatron accelerator and its detector facilities by the end of the decade, and greatly increase the likelihood of major new scientific developments early in the next century. The Main Injector will also allow simultaneous operation of the fixed target and colliding beam research programs, currently not possible.

At the Stanford Linear Accelerator Center (SLAC), the Stanford Linear Collider (SLC) is the world's only operating high energy linear collider. The SLC continues to collect data using its beam of polarized electrons, a capability unique to the SLC which gives physicists an added degree of control over the experimental conditions.

In these experiments, a high energy beam of polarized electrons collides with an unpolarized beam of positrons (the electron's antimatter counterpart) to produce what are referred to as Z particles, the heaviest known elementary particle. More than 100,000 Z particles were observed and recorded by the SLAC Large Detector (SLD) in FY 1995. After analyzing these data, university and laboratory collaborators at SLAC announced the world's most precise measurement of the weak mixing angle, a crucial parameter of the Standard Model of physics. In FY 1997, the SLC is expected to operate for about 26 weeks and, in addition, there will be about 10 weeks of fixed target operation.

Construction at SLAC of the B-factory project, to be completed in 1998, is progressing on schedule and within budget. The B-factory will provide a high luminosity, asymmetric electron-positron colliding beam facility to study the reasons for the preponderance of matter over anti-matter in our universe, a fundamental concept necessary for our very existence. This project will also provide opportunities to pursue a rich program of experiments in a large number of other areas of intense interest in high energy physics. The project is being designed and built by SLAC in collaboration with Lawrence Berkeley and Lawrence Livermore National Laboratories. An international collaboration, about half of which is from the U.S. and half from abroad, is building the BaBar detector, the principal experiment at the B-factory.

The Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory (BNL) delivered protons to 5 running experiments and 15 different test beam groups during its run last year. In addition, its injector linac continues to provide beams for testing materials for the production of radiopharmaceutical isotopes. The AGS recently attained a new world record intensity for synchrotrons, delivering 5.0 x 10^{13} protons per pulse every 3.7 seconds. It is expected that further increases in intensity will be achieved in the near future. These intense beams, although at energies much lower than at Fermilab or SLAC, were used to carry out a program of high precision measurements of very rare decays of particles called kaons, thus providing a critical test of the Standard Model. In FY 1997, the AGS is expected to operate about 15 weeks.

The European Laboratory for Particle Physics (CERN) in Geneva, Switzerland, is beginning construction of a proton collider, called the Large Hadron Collider (LHC). The LHC will be about one-third the energy of that which had been planned for the U.S. Superconducting Super Collider (SSC), but about 7 times the energy of the Fermilab Tevatron. Participation in the LHC is extremely important to the goals of the U.S. High Energy Physics program. Over 500 U.S. physicists are strongly interested in participating in the two major LHC detector collaborations and in magnet/accelerator research and development collaborations. U.S. participation would allow CERN to finish the project at full operating capability in the year 2005 instead of 2008. The FY 1997 budget requests $15 million in support of U.S. scientists' participation in the LHC project.

The extraordinary benefits to the U.S. would include continued access by U.S. physicists to the energy frontier at what will then be the highest energy accelerator in the world. It would ensure continued world class excellence of our university and national laboratory scientists and would provide training to many students in leading edge science and technology. In addition, most of the money the U.S. would spend on detector and accelerator components would be spent in the U.S., with much of it going to industry to build the components. This would improve the capabilities and expertise of U.S. scientists and industries and would ensure their access to the high-level technology being developed. The LHC would be a significant next step toward internationalization of large scientific construction projects, pending successful completion of negotiations with CERN.

Formal negotiation between the U.S. and CERN was inaugurated on January 10, 1996, and is ongoing. An agreement is expected by the end of 1996. This negotiation is guided by an Interagency Working Group consisting of representatives from the Department of Energy, Department of State, Office of Science and Technology Policy, Office of Management and Budget, and the National Science Foundation. In the future, all countries will have to work together to build these necessary but expensive research facilities.

NUCLEAR PHYSICS

FY 1996 Appropriation - $304.5 M, FY 1997 Request - $318.5 M (Figure 9).

The primary goal of nuclear physics research is to understand the structure and properties of atomic nuclei and the fundamental forces between the constituents that form the nucleus. Nuclear processes determine essential physical characteristics of our universe and the composition of the matter that forms it.

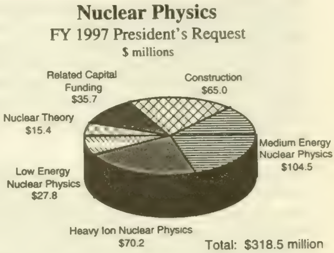


Figure 9

Beyond helping to maintain world leadership in basic research, the Nuclear Physics program develops and transfers knowledge to enhance the Nation's technological and economic competitiveness in such fields as nuclear medicine. The Nuclear Physics program continues to be a vital source of trained people for fundamental research and for these applied technology areas. The program supports the graduate training of approximately 450 students per year, and typically 100 Doctorates in nuclear physics are awarded each year at DOE-supported nuclear physics programs. A majority of these highly trained researchers will take positions in high-technology private industry.

Many future nuclear physics investigations will study questions related to the quark presence in composite nuclei. Until the last few years, the fundamental understanding of nuclear properties has been based on the idea of a nucleus composed of protons and neutrons that interact through a combination of weak, strong, and electromagnetic forces. It became clear that achieving a real knowledge of many nuclear properties depends on understanding nuclear structure based on quarks, and particles called gluons that bind the quarks together. Quarks and gluons are the building blocks of protons and neutrons (nucleons). A new Long Range Plan for the U.S. Nuclear Physics Program, prepared by the nuclear physics community, has been prepared to ensure that we can address the role of quarks in nuclear matter and other most pressing scientific questions.

Studies of nuclear structure require ultra-high resolution "microscopes," accelerators that produce particle beams of very high energy and resolution. The Operating Expenses request is designed to provide the maximum operating hours for these facilities, optimized by funding from the Science User Facilities Initiative, so that researchers may take full advantage of their unique capabilities.

Research at the Continuous Electron Beam Accelerator Facility (CEBAF) will study effects due to the presence of quarks in nucleons in the nucleus. Two principal focuses of these studies will be to continue to develop an understanding of how the "spin" of a nucleus originates in the quarks, and how the size of a quark cluster in a nucleus affects the strength of the interaction of that cluster with other nucleons in the nucleus. However, no one has ever observed a single free quark; they always travel in closely knit groups of threes within nucleons. In FY 1997, CEBAF will operate for 4,500 hours to allow the start up of several high priority experiments to study the quark presence in nuclei.

In addition, the Bates Linear Electron Accelerator at the Massachusetts Institute of Technology will operate for 2,500 hours to take advantage of the new South Hall Ring facility.

A quark-gluon plasma will be produced with a second major facility for the study of new "quark-based" nuclear physics, the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory. RHIC is now under construction and will be completed in FY 1999. It is predicted that if a collection of nucleons could be compressed and heated to a very high temperature by collisions of high energy heavy nuclei, there would be a phase transition to a new state of nuclear matter in which the quarks are "freed" from their nucleon boundaries to form a so-called quark-gluon plasma.

RHIC will be a unique, world-class facility with colliding beams that provide collision energies of 100 billion electron volts (GeV) per nucleon for heavy ions as massive as gold nuclei. The facility will provide the opportunity to form a quark-gluon plasma, creating conditions in the laboratory that are similar to those of the expanding universe microseconds after the Big Bang.

Some of the most critical nuclear reactions in stellar burning processes involve nuclei which, because of their short lifetimes, have not been available for laboratory studies. Another new generation facility, the Radioactive Ion Beam (RIB) Facility at Oak Ridge National Laboratory will produce some of the previously unavailable nuclei so that these important stellar processes can be studied in the laboratory. Beams for experiments will be available in FY 1997 and it will be possible for the first time to study many processes which are crucial to our understanding of how nuclei were synthesized in the Big Bang. The RIB will be operated for 2,400 hours for studies of nuclear measurements of astrophysical significance and for studies of very proton rich nuclei far from stability.

The solar neutrino problem remains one of the great challenges in astrophysics. The predicted rate of neutrino production by the sun is significantly higher than the observed rate. There are two possible explanations for the discrepancy. Either our understanding of solar burning is very wrong, or the neutrino has a small mass, in contradiction to the long-held belief that it is massless. The third major new facility which will be operational in FY 1997 is the Sudbury Neutrino Observatory (SNO) in Canada. Slated to begin data collection in FY 1997, SNO, is designed to sort out this longstanding problem. The project involves an international collaboration among the U.S., United Kingdom, and Canada.

GENERAL SCIENCE PROGRAM DIRECTION

FY 1996 Appropriation - $10.7 M, FY 1997 Request - $11.6 M.

This program provides the Federal staffing resources and associated funding to plan, direct, and manage a viable, high quality national program of basic research in the fields of high energy physics and nuclear physics to ensure U.S. competitiveness in basic research. It supports the staff in the Office of the Associate Director for High Energy and Nuclear Physics, the High Energy Physics Division, the Nuclear Physics Division, and associated program and management support staff both in the Headquarters and at Chicago, Oakland, and Oak Ridge Operations Offices. Beginning in FY 1997, program organizations are contributing to a Working Capital Fund to cover the costs of centrally provided goods and services such as supplies, housing, utilities, etc., which previously were budgeted in Departmental Administration. Appropriate amounts have been included in budget documents to reflect this change.

This concludes my statement. I would be happy to answer your questions.

Chairman ROHRABACHER. Thank you very much, Dr. Krebs. We are joined by Mr. Roemer, the Ranking Member, who undoubtedly now understands that we have been derelict in financing the surface transportation research that would be necessary to get people here on time.

[Laughter.]

Chairman ROHRABACHER. Mr. Roemer.

Mr. ROEMER. Thank you, Mr. Chairman. And, I'm sure that's an endorsement of you and I working together to make sure there is an investment in our infrastructure out there, a bipartisan investment.

Mr. Chairman, I would just ask unanimous consent that my entire statement be entered into the record. Certainly, in my statement, I talk about the size and scope of the laboratories and trying to work with Dr. Krebs and Hazel O'Leary, finding some efficient and wise ways of downsizing those laboratories.

My statement includes a strong emphasis on fusion and high energy physics, a host of other things that I'm very concerned about. You seem to be on a roll, Dr. Krebs. I don't want to interfere with our good witnesses today.

It's always a pleasure to have you before the Committee. And, with that, let's continue to hear from our witnesses and have questions from the panel.

[The prepared statement of Mr. Roemer follows:]

OPENING STATEMENT BY THE HONORABLE TIM ROEMER

RANKING DEMOCRAT

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

HEARING ON ENERGY RESEARCH

MAY 8, 1996

Mr. Chairman, I look forward to this hearing today. It will be useful input to a mark up of an energy R&D authorization bill, which I hope this Subcommittee will consider next Wednesday.

Today we consider the broad portfolio of DOE Energy Research programs. I have a number of questions about these programs, and I will dwell on each briefly now in the hopes of getting to all of them during the question period. But if I do not, I would like to ask the Department to get back to me or my staff with the relevant material in advance of next Wednesday's markup.

First, as DOE well knows, I have been critical about the size and scope of the DOE laboratories. The Secretary has also been concerned about the functioning of the laboratories and she initiated the Laboratory Operations Board to oversee the Laboratories as a unit. I am interested about the progress that this Board has made in streamlining the laboratories and what it intends to do in the near future. I hope that this Subcommittee will work with the Department to accomplish as much as we can together, but I also hope that the Science Committee continues to look at this issue and follows through with its oversight responsibilities in this area.

Another area of great concern to me is that, while most of the energy research programs have been treated with kid-gloves by the Republican Majority during this Congress, the fusion R&D suffered a one-third cut to its budget last year. The program has since struggled to develop a new research plan at these dramatically lower budget levels. With help from the Fusion Energy Advisory Committee and others, I think that they have settled on a viable and productive new course. I, and other supporters of fusion energy R&D, hope that the Congress would now salute their efforts and send them back to work. However, I fear that more cuts and reorganization may be in store for fusion R&D and would like to hear the Department's thoughts on the effect of additional cuts. In particular, it has become common knowledge that the Department initially requested a $200 million funding level from OMB, and I would like to know how DOE planned to sustain a scientifically-sound fusion research effort at that level.

On another front, it has been nearly a year since we've heard testimony on high energy and nuclear physics activities. Since then, the Department has made progress in negotiations with CERN on the construction of the Large Hadron Collider. I am looking forward to a discussion of where DOE plans to go with this collaboration and would ask the Department to provide its most up-to-date summary of those efforts.

In recent years, I also have become more familiar with the high energy and nuclear physics and basic energy research activities at the University of Notre Dame, and I am interested to hear DOE's view of the role that the Notre Dame Radiation Laboratory may play in the coming decade.

On another topic, the Biological and Environmental Research program supports a diverse array of experiments in such areas as biological processes, environmental remediation, and oceanography. With the cutbacks instituted by Congress in this program, DOE has had to prioritize its efforts. I hope to receive an update on the reorganization of this program under the current budget and for the declining budgets envisioned by the Administration for these accounts.

Finally, the Office of Energy Research recently began a competitive research effort to support long-term research on environmental restoration and waste management science. Funded at $50 million from the defense accounts at DOE, this program set aside $20 million for university research, $20 million for DOE laboratory research, and $10 million for integrative research. I am interested in how the Department arrived at these allocations and how the competitions will be run in the coming months.

These programs are at the core of the activities that the Science Committee authorizes at the Department of Energy. I look forward to the testimony that we will hear today and thank the witnesses for coming to share their thoughts with us. Thank you, Mr. Chairman.

Chairman ROHRABACHER. Without objection, your full statement will be placed in the record.

We are also joined by Congressmen Minge and Bartlett and Ehlers. And, do any of you have an opening statement that you would like to place in the record?

Mr. EHLERS. No.

Mr. BARTLETT. No.

Mr. MINGE. No.

Chairman ROHRABACHER. Okay. We have—it is custom now that the Ranking Member and the Chairman have opening statements and other members would just be free to place opening statements in the record.

So, I will proceed with a few questions. And, then we will move on to other Members of the Committee.

Dr. Krebs, it was reported by "Inside Energy", and not denied by the DOE, that your initial request submitted to the OMB for Fusion Energy was $200 million. The official request is now $255 million.

Where did the extra $55 million come from? And, what specific programs in your office were reduced to accommodate this increase?

Dr. KREBS. Let me put a little perspective on your statement. And, then I will answer your questions.

If you remember, we made this proposal—the initial request was formulated in the August/September time frame of 1995. At that point, the House and Senate marks were $229 and $225 million, respectively. The Chairman of Appropriations had marked it $204 million going in.

In the face of that, the fusion community was not prepared to consider what the program would look like at those numbers. I had a hard target or cap that I was—you know, that I was asked to make recommendations to.

I did go forward or recommended a $200 million program to the OMB. But, that number was not informed by any intelligence, no more intelligence, in fact, than I believe was in forming what Congressional action at that time was.

The $244 million—so I went forward with a number that I believed or hoped—with the hope and expectation that the fusion community would be able to justify the right kind of restructured program. We went forward as soon as we had the final mark from Appropriations to gather the fusion community together.

I also had the hope and expectation that when the fusion community gave us a credible approach to the future that in the discussions and, you know, balances that were made in the budget process in the Administration that they would find the funding necessary to acknowledge what the community proposed. Both the community and the Administration fulfilled my expectations.

And, so I have no problem representing this budget and believe that it is credible and the right thing to do.

In terms of how that funding was found, it has not hurt, to my knowledge, any of the programs in Energy Research.

Chairman ROHRABACHER. The tooth fairy just came along and left it under the pillow or something?

Dr. KREBS. The—no. As I said, I think there are many discussions and balances that are made in the Administration's process. But, they did not find this money from Energy Research.

Chairman ROHRABACHER. They didn't cut any of the other programs that you had suggested in order to find the extra $55 million?

Dr. KREBS. Well, there were discussions about other programs in education, I believe. But, that was about it in terms of the science programs.

Chairman ROHRABACHER. So, there was some—in order to obtain the $55 million, there was some discussion and perhaps some cutting of education programs?

Dr. KREBS. You could interpret it that way if you looked at our budget. But, basically, I don't think that it hurt the science programs.

Chairman ROHRABACHER. All right. Well, I appreciate that you have a responsibility also to keep discussions that—you know, you are trying to have honest discussions behind the scenes, but I also appreciate you trying to be as forthright with us as possible. So, I appreciate that.

The Clinton Administration balanced budget plan calls for a sharp drop in funding for high energy and nuclear physics beginning in 1998 through the year 2000 and then major increases from 2001 and 2002. Did the DOE have any input in the development of those figures?

Dr. KREBS. The way I understand this from having heard both the Secretary and the Deputy Secretary describe this is that we did not, that we—that our understanding is that these reductions were made at the end of the budget process and were applied in a mechanical way, that they do not represent policy and——

Chairman ROHRABACHER. They don't represent policy?

Dr. KREBS. They do not represent policy and a judgment about the value of the programs in the Department, and particularly the values of either the High Energy Physics programs or the other programs in the Office of Energy Research, and that it is our expectation that these issues will be revisited after the Congress marks the 1997 budget and we enter into our formulation of the 1998 budget.

Chairman ROHRABACHER. Dr. Krebs, I am not going to try to be—you know, this is not—I'm not saying this in a partisan way, although this is the middle of an election year and I am not saying this——

Dr. KREBS. Right.

Chairman ROHRABACHER. But, what you just said basically plays into everything the Republicans have been saying about the Administration, that the Administration is giving us phoney numbers based on something that does not represent policy, does not represent a well thought out plan and that the Administration does not really wish to balance the budget but instead is just presenting something phoney to the public in the meantime. And, I mean, I don't want to—you are a professional and you are trying to do your job.

But, I will just have to say that what you just said confirms everything that I've been thinking and that a lot of other Republicans have been thinking.

Please feel free to come back if you want to on that.

Dr. KREBS. I don't believe that the Administration is not committed to these programs. But, I do believe that I think that it is important for the Congress and the Administration to work together to give each other the correct messages about the value of programs such as are in the Office of Energy Research for the outyears.

Chairman ROHRABACHER. Well, sometimes it takes—it's really very difficult to set priorities when you have to work within a limited budget. That's true for a family. It's true for an individual. It's true for a business. And, it's true for government.

And, what we have is some very erratic figures in terms of this research. And, I am just going to have to say that—I mean, I've been told time and again by the, you know, high energy and nuclear physics people that what they really want to know is what they can do for—you know, what they can work with and what they can project-out so that they can know the most they can accomplish with the amount of funds that are available.

And, what you've given us is basically something that is erratic. And, now you are telling us it's irrelevant as well.

Dr. KREBS. What I can say is that the leadership of the Department understands that the Office of Energy Research programs are comparable to the contribution—the contribution of the Energy Research programs are comparable to the contributions that the National Institutes of Health and the National Science Foundation make and view that in the outyears that they should be treated comparably.

Chairman ROHRABACHER. All right. Well, it was reported in "Inside Energy" again, and not denied by the DOE, that your office—or, excuse me, that the Office of Management and Budget, the

OMB, added over $100 million to your agency's request for energy conservation. That's primarily for market development and promotion programs.

Did these additions result in any reductions in energy research programs?

Dr. KREBS. Not to my knowledge.

Chairman ROHRABACHER. Okay. The tooth fairy again has visited the scene and just left a little——

Dr. KREBS. You have—you clearly—you have the—you know, you have information about the numbers with which we went into OMB. And, I think that with—in terms of the underlying science programs, which are the majority of what we are about, these programs, you know, did not change.

The programs that changed were basically Fusion and Nuclear Physics and to the better.

Chairman ROHRABACHER. Well, it seems that what my staff and what the Committee staff has gleaned from going over the figures is that OMB did give you another $100 million and it was not just for that, but it was—it included extra money for development programs and promotional programs.

Dr. KREBS. I agree. That's true, but I do not believe that that increase had an impact on, you know, any additional reductions to the Office of Energy Research.

Chairman ROHRABACHER. Okay. Again, as I said in my opening statement, you know, when you are trying to set priorities, at least we set out, the majority of the Committee set out, and I believe that even the Minority of the Committee agreed with this, that research should be—research and development should be the number one priority of this Subcommittee.

And, again, unless you are willing to set priorities, you have a lot of—there's difficulty in making budget decisions. And, that's what budget decisions are all about.

When you have an expanding budget, it's very easy to do. I mean, it's extremely easy to set priorities in an expanding budget, because nobody is getting cut.

But, when you are having to say that you have to live within a limited budget, that's totally different.

I have one more question, but I think I will move on to our Ranking Member here and then on to the others and let them have their chance. And, I will follow up at the end.

Mr. Roemer.

Mr. ROEMER. Thank you, Mr. Chairman. Dr. Krebs, you know that I am a big supporter of the National Laboratories.

As we move into a new millennium and a brand new century, I also strongly support seeing some of these laboratories do some missions differently and work more closely in partnership with the private sector. And, I'm very concerned that we are not doing that quickly enough and closely enough with the private sector.

We've seen the report from Mr. Galvin. We have now seen Secretary O'Leary create the Laboratory Operations Board to try to see what we can do about some of the duplication and some of the mission creep and some of the excessive costs.

Can you tell me specifically what this Board has accomplished to date?

Dr. KREBS. Well, the Board, on which I sit as one of the internal members, is also composed—you know, it's composed equally of members from outside of the Department, both industry, academia and other interested areas of the—you know, the constituency of the laboratory, as well as internal members such as myself and various other principal secretarial officers like the Assistant Secretary for Environmental Management. But, it's chaired by Charles Curtis, our Deputy.

In the last—since its creation last year, the Committee—the Board has primarily looked at the Department's delivering on the commitments for action to the Galvin report. And, it's basically an oversight organization.

And, as a result, it has helped to push the Department in delivering on, for example, the revision to environment, health and safety oversight that we are calling necessary and sufficient, which hopefully will enable the laboratories to use to the greatest extent possible external regulatory requirements as opposed to those which are generated inside the Department. It has reviewed and approved the reduction of business oversight processes.

It has reviewed the activities that the laboratories are carrying out to reduce costs themselves. And, there are a number of other activities which I would like to provide you for the record.

Mr. ROEMER. I would appreciate that, Dr. Krebs. It sounds like it's doing more to kind of oversee and track the Galvin report rather than really being innovative and providing leadership in terms of some of these areas that we would really like to see you move into.

Dr. KREBS. Well, they have also begun—you know, they also were in the—you know, provided a great deal of discussion and added value to the formulation of the Strategic Lab Mission Plan, which is right now sort of a snapshot of where we are as opposed to where we need to go. But, I think that the expectation is that as we move forward past the first phase of delivering on the Galvin report that we will begin to get into these kinds of areas that will focus on balancing the investments in the laboratories, between the laboratories and other areas of the—you know, the R&D performing organizations.

And, there is—but, I would like to say also that independent of the Operations Board, within the Department and within the Department's programs, there are efforts to strengthen the collaborations between laboratories and universities, between laboratories and the private sector, that this isn't being—this is not just the purview of the Laboratory Operations Board. You know, the programs themselves took the messages very strongly and are developing programs.

I think if Christine Ervin were here, she would talk about industries of the future. And, Energy Research is working with that program.

When I think about it, I think about, you know, the dedication of the Advanced Photon Source with, you know, many collaborative access teams driven by major participation from industry.

Mr. ROEMER. Well, we want to continue to see that collaboration and the leadership and innovation and reform, and not just tracking.

Dr. KREBS. Right.

Mr. ROEMER. You know, for instance, on the external review versus internal review, we would hope instead of tracking that and studying that and reviewing that and so forth, it just makes a heck of a lot of common sense to move toward the external review and not toward this internal process that adds cost and layer and layer of bureaucracy and oversight and so forth. So, we hope that we can work with you in these areas.

And, I recently had a meeting with the Secretary in my office to talk about these things. And, we hope the time frame and the results can be a little bit more leadership-oriented and innovative than it has been.

And, I look forward to working with you on that, too.

Dr. KREBS. Fine.

Chairman ROHRABACHER. Thank you, Mr. Roemer. Mr. Minge.

Mr. MINGE. Thank you, Mr. Chairman. Although I have several things that interest me, I would like to just focus on one topic.

And, that is the Superconducting Super Collider which, of course, is no longer being constructed. And, as I understand it, you have recently announced that there is a tentative agreement with CERN that this country would contribute something in the neighborhood of $450 million for the construction and outfitting of that particular facility.

And, I'm interested in knowing first if you view the decision not to build the Superconducting Super Collider, something that is handicapping American research and the ability to develop opportunities in this country; or, looking at it from an alternative perspective, are we able to contribute to the CERN in such a way and participate in the use of that facility so that it is an adequate alternative?

Dr. KREBS. Well, the loss of the Superconducting Super Collider was a real tragedy for American science and for the high energy physics effort in this country. The Department and the High-Energy Physics Program in the Department, which supports 90 percent of the work in high-energy physics in this country, requested, you know, when we lost the SSC that the community take a look at what was necessary to maintain vitality in, you know, the decade of the 90s and into the first decade of the next century.

They recognized that the capabilities of the Large Hadron Collider would be less, but nonetheless it is the energy frontier. It was viewed as something that to sustain vitality in this country we would have to be part of it.

It is very clear to me in the negotiations that we've had thus far—and I have to say that what we—we have not finished these negotiations, that the number that we have agreed to is one in which we have set two technical working groups to work, you know, sort of laying out what is possible and what advantages there would be to the U.S. program and to CERN. But, it is not yet foregone exactly what the final number will be.

But, it is very clear to me in these discussions that the U.S. community has something very vital to offer CERN. So, we offer them an advantage simply by our people and our capabilities that exist in our laboratories and in our university investigators.

And, of course, being at the frontier offers them a way to stay vital. In the long term, the very long term, because it's really hard to think—you know, it gets really long term when you are thinking 15 years out, I think it is going to be important for this country to have its own capability at the frontier, because that's what will keep American young people engaged in this field.

Mr. MINGE. So, you don't feel that the project in Switzerland will be adequate for researchers in this country?

Dr. KREBS. In the long, long term, yeah, beyond 15 years. But, I think it will be—it will be adequate to stay at the energy frontier.

There will be other facilities that I think—you know, we are now putting Fermi and the Stanford Linear Accelerator into a position where they will be able also to operate at the high intensity frontier, if you will, in the first decade of the next century as well. And, because we cannot predict where the most exciting science is going to arise, I think we will want to keep—maintain those facilities as well.

But, I think you can talk to Dr. Peoples and Dr. Richter and they will tell a much more intense story about what is important about those facilities in this coming 15 years.

Mr. MINGE. And, then one other aspect of that. At several of the colleges and universities I visited, there was concern about the investment of the Superconducting Super Collider, because they felt it took a very substantial amount of the basic research money for one project.

Have you found that now that we are not continuing with that project that it has been possible to save a portion of the funds that were to have been invested in it and used those funds for any other basic research?

Dr. KREBS. That money is gone.

Mr. MINGE. Okay. So, it's not——

Dr. KREBS. It didn't go anyplace else in the Department of Energy. It didn't go anyplace else in science.

And, if I can make a comment, I think that one of the problems that we face in the coming years as we face tight budgets, the real challenge to the scientific community is not to fight among themselves, because when you fight amongst yourselves the money goes. It doesn't go to any other part of science.

It's a real danger. If I could give you a message, it's to tell your—you know, when you visit universities, if you talk to biologists or chemists who have some concerns about whether or not the SSC or the genome or any of these large science projects affect other exciting opportunities, if they attack this money it goes. It doesn't come back anyplace else.

Mr. MINGE. The one message I would like to give to the large projects is if they seek a disproportionate share of the money, it creates a very tense and competitive arrangement with their colleagues and it leads to the internal sniping which certainly gets on the outside.

Chairman ROHRABACHER. Thank you very much, Mr. Minge. I would just—taking the Chairman's prerogative, I would just say that it doesn't just go. It arrives, delivered by the tooth fairy to various little projects all up and down the line. And, that's where it goes.

I mean, I believe that the law—you guys know more about the law of physics than I do, but I mean there is something about things not being created or destroyed. And, this is part of it.

I mean, if you squeeze the balloon it's going to go someplace else. Hopefully, eventually it will go into the taxpayers' pockets so that they can pay the bill for educating their children or for a new car or something else.

Dr. KREBS. It didn't go to basic research.

Chairman ROHRABACHER. That's right. It went to marketing and development programs and——

Dr. KREBS. No.

Chairman ROHRABACHER. (continuing) —all these other things.

Dr. KREBS. No.

Chairman ROHRABACHER. Mr. Bartlett, Dr. Bartlett. No, no, that's unfair of me.

Go right ahead.

Dr. KREBS. No, that's all right.

Chairman ROHRABACHER. Dr. Bartlett, go right ahead.

Mr. BARTLETT. Thank you very much. Welcome again, Dr. Krebs. I suspect that Dr. Ehlers may bring a somewhat different perspective to this subject and to these hearings. The recent gas price increases at the pump have reminded us anew that energy is very important in our society and in our economy.

Every year since the 1970s, we have in this country found less oil and pumped less oil. We now get fully half of our oil from overseas.

We produce about 20 percent of our electricity with nuclear. And, that will shrink to 0 percent early in the next century.

Prudhoe Bay now has pumped about three-fourths of all of the oil that was there. And, if we go into ANWR, we will find a scant 3 billion more barrels. There's roughly that many to pump out of Prudhoe Bay from about 13 billion that was originally there.

As we look to the future, clearly there is going to be a diminished, readily available supply of oil and gas. And, if we are going to stay with fossil fuels, we will be moving increasingly to coal where one pays a relatively high environmental penalty for using coal or for converting coal to gas or oil so that it can be more conveniently used in many of our processes.

Add to that something that we scarce think about and that is the enormous petrochemical industry that requires as its base right now today gas and oil. To a large degree, it can be said that our gas and oil is really too good to burn.

And, here we are using it at such a fierce pace that the supplies remaining in the world are clearly not without limit. My concern as we look to the future and with our budget constraints, do we have in your Department and in the Administration any energy policy for the future or are we just trusting to dumb luck that somehow it will be okay?

Dr. KREBS. The——

Mr. BARTLETT. I have not heard an energy policy articulated anywhere in this city.

Dr. KREBS. I believe that the Secretary of Energy has proposed an energy policy. As you know, we are actually required to publish an energy policy plan, I think, every two years.

One came out last year. And, of course, part of our energy policy, a major element of our energy policy, is a balanced research and development plan.

And, in fact, a fairly substantial element of our funding goes to that energy R&D plan. My programs are part of that.

And, in fact, the Basic Energy Sciences program, the Fusion program, the Biological and Environmental Research program are part of that strategy, as is the Energy Efficiency Renewables and Fossil Energy program. I think that there has been, you know, a profound disagreement between the Congress and the Administration over the last year and a half certainly.

But, even before that, I think that it has been very hard for any administration and the Congress to come together on what represents the right portfolio for investment in R&D. There are other issues associated with regulation, with development of resources and with pricing that I'm simply not competent, let alone prepared, to sort of address with you at this time.

And, I would be happy to provide you with what I think are the statements of the Administration relative to an energy policy. [See Appendix.]

Mr. BARTLETT. Is it politically correct within your Department and the Administration to suggest that we may have a future which cannot include the enormous dependence that we now have on fossil fuels? Or is that a politically incorrect position, as it is many other places?

Dr. KREBS. I believe that this Administration has taken very seriously the need to shift dependencies on fossil fuels particularly and to shift the dependencies among the fossil fuels and to emphasize energy efficiency and to emphasize clean fuel—clean energy conversion processes such as fusion. And, so I think this Administration very strongly recognizes the need to shift away from fossil fuels.

So, I think it's very legitimate, you know, within this Administration to talk about that.

Mr. BARTLETT. Thank you very much. And, I know my time is up, Mr. Chairman.

I would suggest that we might profitably have a hearing in which we looked at our country's energy future and take a long range look at where we are and where we need to be going if we are not going to potentially come to grief in the not too far distant future. Thank you very much.

Chairman ROHRABACHER. Thank you, Dr. Bartlett. Now, Dr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman. I will be very brief, because I am anxious to get the panel up there in view of all the time constraints we have and going into session very shortly.

I would just like to associate myself with the comments of Dr. Bartlett. I agree totally with him.

I am very concerned about this issue. I am concerned about the reductions in funding for fusion research.

I think FEAC did a very good job last year trying to prioritize the programs and came up with a base figure of $275 million to maintain. And, I would certainly like to see it funded at that level.

Also, in terms of energy efficiency research, energy conservation, all of those areas are extremely important to our energy future. And, as Congressman Bartlett pointed out, this has come to public attention once again with the recent increase in fuel prices.

And, my experience in dealing with the public, the impression is the energy crisis came, we conquered it and the problem is done. That's simply not true, but that's the way the public perceives it. And, they are getting a little slight reminder that it's not over.

I would hope that the Department would continue to try to emphasize this both in educating the public to the real nature of the problem and allocating appropriate resources to that. I realize that Congress also bears responsibility for that.

As you well know, we have not always funded it as we should. But, I think we have to work together on that and develop a good program.

With that, Mr. Chairman, I will yield back the balance of my time in the interest of proceeding rapidly to the panels. Thank you.

Chairman ROHRABACHER. Mr. Wamp.

Mr. WAMP. Thank you, Mr. Chairman. I will also be brief.

Dr. Krebs, I want to say in my short tenure here that I've met a lot of important people from both sides of the aisle in the Administration and in the legislative branch. I have not met anyone that is more professional than you.

I have not met anyone who is more candid than you or that is more apolitical and genuine than you. You would be a credit to a Republican or a Democratic Administration. And, I mean that sincerely.

I know everybody at DOE. And, she is right at the top.

A question for this Committee. Long term, we have a lot of inventory of equipment, very important equipment, throughout the complex. Some of it needs to be maintained. Some of it needs to be upgraded.

In my district, I know that our High Flux Isotope Reactor is going to need to be upgraded in the near future. What can you—how can you instruct this Committee to look long term across the complex, not just in Oak Ridge, but Los Alamos or wherever other very important pieces of equipment—some machines need to be maintained and upgraded to the fullest potential.

What should we do to make sure that we take the best care of our equipment and also avoid the excessive cost of building new equipment where our budget may not allow it in the near term?

How can we be more efficient as we prepare for the future with our scarce budget resources?

Dr. KREBS. Well, as you know, Mr. Wamp, the Department and the Office of Energy Research requested its Basic Energy Science Advisory Committee to give it advice on both assuring eminence and preeminence in neutron science. They came out with a report that recommended that while maintaining the base that we move forward with the design of the High Flux Spallation Neutron Source, but also invest in upgrades—the High Flux Isotope Reactor, the High Flux Beam Reactor at Brookhaven and a possible investment in spallation sources in intermediate scale. Spallation sources was also recommended.

We are in the position now—I believe and I think there is no question that neutron science has been something that the Department of Energy has pioneered. Cliff Shull at Oak Ridge National Laboratory won the 1994 Nobel Prize in Physics because of the investment by the Department of Energy. Neutron science is an area of research that permits, encourages, draws in collaborations between our national laboratory scientists and industry.

And, we are in danger of losing eminence, not just preeminence but eminence in that field. So, I feel very strongly about the need to move forward with a plan to develop these upgrades.

It will not be for free, but it's certainly not major investments. I am expecting to forward such a plan in the very near future to the Secretary and the Deputy Secretary.

And, as that moves forward within the Administration, I think we will be prepared to share that with you as well. And, I think we need to have that discussion in the next few months.

It is very much an issue as to what the treatment—you know, how we need to think about the contributions of the Office of Energy Research as part of the science investment by the country and how the contributions of the Office of Energy Research stack up with other agencies that invest in basic science.

Mr. WAMP. Thank you, Dr. Krebs. I yield back, Mr. Chairman.

Chairman ROHRABACHER. Thank you, Mr. Wamp. Just two more questions from the Chair.

You've outlined a program for funding the Large Hadron Collider in Europe that would cost about $500 million over a period of years. Yet, we've already spent millions of dollars to construct a Stanford Linear Accelerator Center and the Heavy Ion Collider at Brookhaven and another accelerator facility at Newport News.

Basically, when we have tight budgets, how can we justify spending $500 million more for this European collider when we've obviously spent considerable sums on colliders here in the United States already?

Dr. KREBS. Number One, just when I think about the level of investment we are talking about, it's $450 million. It's plus or minus 50. But, my thinking is really $450 million.

Chairman ROHRABACHER. But, you have already said that, you know, the outyears are going to be revisited. You know, they seem to be always revisited up instead of down.

Dr. KREBS. Well—$450 million is what I've been—you know, what I have my mind on and my sights on.

Chairman ROHRABACHER. Believe me, if it comes in at $450 million, it will be further proof of the existence of God.

[Laughter.]

Chairman ROHRABACHER. So, go right ahead.

Dr. KREBS. But, besides that, I mean, that's the—the issue is each of these facilities is aimed at answering different kinds of scientific questions. And, in particular, in high energy physics, you know, it's named high energy physics. We go to the energy frontier. The energy frontier is going to be at CERN.

And, you know, the United States—that participation in high energy physics, leading high energy physics, which is what we have done for the last 50 years, has basically, you know, been part of what makes us the envy of the world amongst our competitors in other nations. And, if you decide to make an allocation to these programs that does not permit us to go forward with the Large Hadron Collider, then you are basically saying you don't want to lead the world.

And, I can't recommend that. And, these other machines do not fill the bill.

Chairman ROHRABACHER. Well, last year, when you asked for funds, it was in anticipation of an agreement with Europe on a Hadron Collider. And, you are asking for funds again this year.

But, I understand there is still no specific agreement. Is that right?

Dr. KREBS. We expect to have an agreement by the end of this fiscal year, by September or October.

Chairman ROHRABACHER. And, so there is still no agreement?

Dr. KREBS. We are in the process of negotiations.

Chairman ROHRABACHER. Wasn't it your position last year that you thought that we would have an agreement by now?

Dr. KREBS. No. I believe the position was we would negotiate it in 1996, by 1996, that it would still be ongoing in 1996, the negotiation.

Chairman ROHRABACHER. Okay.

Dr. KREBS. I will check that. But, that's what I believe.

Chairman ROHRABACHER. Okay. So, the agreement hasn't been reached, but you are dead certain that it's going to be only—only require $450 million?

Dr. KREBS. Yes. I don't want to go above that. I don't think we have the money to go above it.

Chairman ROHRABACHER. Some people don't think we have money to go below it either. So, what we should do—thank you very much, Dr. Krebs.

Let me just say I appreciate you coming here. And, I will give you the last word.

Whereas you are here in the hot seat, would you like to give us a one minute summary of what you think some of the highlights or some of the most important elements that we've touched on today and your impression of them?

Dr. KREBS. Well, let me just reiterate my last couple of comments in my testimony, which is that the Office of Energy Research sponsors some of the most exciting research in this country, that we have investments in people and facilities at both our great national laboratories and our universities, that they measure up both in terms of quality and contribution to any other agency in this government, and that this is an important part of our investment. And, I really hope that the Congress doesn't forget that.

Chairman ROHRABACHER. Thank you, Dr. Krebs. We know you served on this Committee in the past and have an insight and knowledge of both sides of the table now.

So, thank you very much. And, I would just like to say that Ms. Cubin from Wyoming has arrived.

She has no opening statement, I understand. Or, you do? No opening statement?

Ms. CUBIN. No.

Chairman ROHRABACHER. We recognize your presence with us. And, thank you.

And, thank you, Dr. Krebs.

Dr. KREBS. Thank you.

PANEL 1—DOE HIGH ENERGY AND NUCLEAR PHYSICS LABORATORY DIRECTORS

Chairman ROHRABACHER. The first panel will please be seated.

Our first panel consists of Directors from the Department of Energy's High Energy and Nuclear Physics Facilities. Dr. John Peoples is Director of the Fermi National Accelerator Laboratory in Illinois.

Dr. Burton Richter is the Director at the Stanford Linear Accelerator Center in California. Dr. Nicholas Samios is Director of Brookhaven National Laboratory in New York. And, Dr. Herman Grunder serves as Director of the Continuous Electron Beam Accelerator Facility, CEBAF.

Gentlemen, your full testimony will be put in the record. And, I would hope, if you could give us time to ask you some questions, if you could keep it down to about five minutes that would be very much appreciated, because we have some of our Members here who are very interested in asking you specific questions.

So, thank you very much. And, Dr. Peoples, could you start?

STATEMENT OF DR. JOHN PEOPLES, JR., DIRECTOR, FERMI NATIONAL ACCELERATOR LABORATORY, BATAVIA, ILLINOIS

Dr. PEOPLES. Chairman Rohrabacher and distinguished Members of the Subcommittee, Fermilab is managed by the University Research Association. That's a consortium of 83 universities, certainly an example of a university/government partnership that's been in existence for now 35 years.

I am honored that you have asked me to speak about the Office of Energy Research programs at Fermilab. Let me start with a few words about a discovery made at Fermilab since I testified to you last year.

At that time, the list of known subatomic particles included only five quarks. Just two weeks later, the scientists at Fermilab announced that they had discovered the top quark, ending a search that began with the discovery of the bottom quark almost two days ago. So, now, in fact, there are six.

Now, to physicists, at least, this world with six quarks is very different from one with only five. The theoretical framework that provides our best explanation of the properties of matter would be incomplete and incomprehensible without the sixth quark.

While the top quark fits comfortably within our expectations, its discovery sharpens our interest in a fundamental question of physics. Why do quarks have mass? What is the top quark 50,000 times heavier than its sister, the up quark?

Now, I'm asked this question. How does the top quark affect the man in the street? Now, I have to come with a little bit of an answer.

If the up quark were just a little heavier than the down quark rather than the other way around, there would be no man in the street. There would be no street.

The masses of these quarks matter. Exploring the properties of the top quark is one way for us to gain insight into the origin of the masses of quarks.

This is where Fermilab comes in. Fermilab is a program dedicated laboratory, dedicated to the search for an understanding of particle physics.

We operate the Tevatron, the highest energy accelerator in the world, and its detectors with about 2,600 scientists, nearly all of whom come from universities in the United States. Together, these facilities provide the data that takes particle physics from the realm of speculation to a real understanding of the nature of subatomic matter.

We are building the Main Injector and rebuilding the collider detectors to produce data five times faster than we did a year ago when we made this discovery. It is only through data that we will answer these fundamental questions.

Fermilab operates a single accelerator facility that consists of a chain of three proton accelerators, two storage rings to accumulate antiprotons and the final accelerator, the Tevatron, the highest energy accelerator in the world. Although they are separate, Fermilab accelerators are part of a single, scientific instrument.

Each is required for the whole to work. The laboratory does not have the option of operating only some of the accelerators.

It's sort of an all or nothing proposition. Although we can use the Tevatron, either for what we call collider physics or fixed target physics, but not for both at the same time.

Now, at this moment, Fermilab is in the midst of the transition from collider operations to fixed target operations. In June, we will begin extracting a beam of protons from the Tevatron.

By directing this beam on to eight targets, we will create eight distinct particle beams that will in turn support 10 unique experiments. Although fixed target experiments cannot explore the high energy frontier of particle physics, as the Tevatron collider experiments do, they probe very precise questions about subtle, still unexplained phenomena discovered earlier. Now, typically, these discoveries were made at lower energies.

The Main Injector is moving rapidly towards completion.The project is on budget and will be completed within the total estimated cost of $229.6 million and will be on schedule if the $52 million request for FY-1997 is enacted.

When the Main Injector begins routine operation, then for the first time Fermilab will be able to simultaneously operate the Tevatron as a collider and the Main Injector as a source of fixed target beams. We are not without problems, however.

While the proposed budget for facilities operation at Fermilab in FY-1997, including the Scientific Facilities Initiative, is slightly less than the budget enacted in FY-1996, we believe that it will allow 32 weeks of operation. In FY-1997, we must accommodate nearly $5 million in additional costs from the increased expenses due to electrical power and cryogenics that are incurred by fixed target operations.

The average salary cost per employee will increase by somewhat more than 3 percent. In 1995 and 1996, we held these increases to less than 3 percent.

In order to control our costs, we have reduced the staff from 2,400 to 2,100 people since 1992. I note that it was in 1992 when we were working with the SSC that we were the largest that we have been. So, we have gotten smaller.

We are going to have to continue to offset salary increases with staff reductions. Two months ago, we adopted a plan that will decrease the staff by an additional 75 people over the next nine months.

With fewer people, we have had to make reductions in our scientific program. We have made reductions in what are called overhead and these things, but from here on in those reductions are going to be in the program.

Fermilab and my colleagues to my left have very efficient and well run operations. We don't have a whole lot in nonproductive or nonscientific efforts.

Throughout the past——

Chairman ROHRABACHER. Mr. Peoples, if you could summarize now, because we are going——

Dr. PEOPLES. I'm just doing that. I'm right at that point.

Throughout the past five decades, each Congress and Administration has supported the nation's high energy physics program. Now, initially, this support made the U.S. the clear world leader.

American scientists created the field of high energy physics and gave it a distinctly American stamp. Today, we are able to keep our place among the leaders but we are no longer the leader.

Now, I support the Administration's FY-1997 budget request. It is balanced between facilities operations and investment in new capability.

As we look toward the year and the decade to come, we believe that more discoveries await us if we have the resources to pursue them. And, I hope that we can continue to enjoy your support even in this time of very tight budgets.

I'm finished.

[The prepared statement of Dr. Peoples follows:]

Testimony to the Subcommittee on Energy and Environment
House Science Committee

"The Department of Energy's Energy Research Programs at Fermilab and the Scientific Facilities Initiative"

May 8, 1996

Dr. John Peoples, Director
Fermi National Accelerator Laboratory

Chairman Rohrabacher and distinguished members of the subcommittee: I am John Peoples, director of Fermi National Accelerator Laboratory in Batavia, Illinois. Fermilab is one of three U.S. Department of Energy laboratories that operate particle accelerators for high-energy physics research. I am honored that you have asked me to speak to you about the Office of Energy Research programs at Fermilab.

Top Quark

Before commenting on the 1997 budget, I want to say a few words about a discovery made at Fermilab since I last testified before you on February 15, 1995. At that time the list of known subatomic particles included just five quarks. We physicists expected that the sixth and presumably last quark would soon join the list. Even then scientists working at Fermilab had accumulated strong evidence for it. Just two weeks after I spoke to you, two groups of scientists at Fermilab announced that they had independently discovered the top quark. So now, in fact, there are six.

Their announcement ended a search that began with the discovery of the bottom quark at Fermilab almost two decades ago. The discovery of the top did not come easily; over the years, thousands of scientists at five accelerator laboratories in four countries searched for it. Ultimately, the discovery was made at Fermilab's Tevatron, the only collider that can reach the energy needed to produce a top quark.

To physicists, at least, a world with six quarks is very different from a world with only five. The Standard Model, the theoretical framework that provides our best explanation of the properties of quarks and leptons, would be incomplete and incomprehensible without the sixth quark. Yet, while the top quark fits comfortably within the Standard Model, its discovery sharpens our interest in a fundamental unanswered question of physics: Why do quarks have mass? Why is the top quark so massive? It is more than 50,000 times heavier than its familiar sister, the up quark. (The up and down quarks make up protons and neutrons, key constituents of everyday matter.) Or are we asking the wrong question? Maybe we should ask why the other five quarks are so light. We have no clue why the up and down quarks and the electron are so light, but we do have a hint why the top quark is so heavy.

Occasionally I am asked how this question affects the man in the street. If the masses of these particles were just a bit different, if the up quark were just a little heavier than the down quark, there would be no street and no man to ask why we want to know about quarks. The value of these masses matters. Exploring the properties of the top quark may give us insight into the origin of the masses of the quarks and the leptons.

Physicists Beguiled

Now, a year after the capture of the top, scientists at Fermilab have hints that they may be approaching another major discovery. They may be seeing evidence for phenomena not explained by the Standard Model. If these phenomena do not represent a statistical fluke or a bad day at the detector, it will take new physics to explain them; and the new physics could lead to a unification of the fundamental forces of nature in a way that takes us beyond the Standard Model. It is still possible that these hints are merely very unlikely chance occurrences of events in one of the detectors. In the meantime, though, their mere existence has led to a frenzy of speculation about what they may portend. Whenever scientists push against the frontier of knowledge, they glimpse a new landscape of the imagination. "Rare Sightings Beguile Physicists," said a Science magazine story on these intriguing new phenomena. Gary Taubes, the author, described the disagreements among physicists about the meaning of the new events. "In the end, he wrote, "the data will win out, as they always do."

Fermilab's Role

That is where Fermilab comes in. Fermilab is a program-dedicated laboratory: dedicated to the search for an understanding of particle physics. The Tevatron and its detectors provide the data that take particle physics from the realm of speculation to the plane of actual discoveries about the true fundamental nature of matter. At Fermilab, we have done this with detectors that sifted through nearly ten trillion antiproton-proton collisions to find about 100 containing top quarks. The various theoretical possibilities can only be resolved by searching more deeply. This is why we are building the Main Injector and rebuilding the collider detectors—to produce and record antiproton-proton collisions five times faster than we did a year ago. The data describing these collisions will, in the end, win out.

Fermilab operates a single accelerator facility that consists of an injection chain of three proton accelerators, two storage rings to accumulate antiprotons, and the final accelerator, the Tevatron. Protons move up through the chain of accelerators, gaining energy in each one, until they reach an energy just shy of one trillion electron volts in the Tevatron. Currently, Fermilab scientists can use these high-energy protons for either collider physics or fixed-target physics, but not for both at the same time. In 1999, the Main Injector will replace the Main Ring, and then, for the first time, Fermilab will be able simultaneously to operate the Tevatron as a collider and the Main Injector as a source of 120 GeV fixed target beams.

Transition from Collider to Fixed Target

At this moment, Fermilab is in the midst of making the four-month transition from collider operations to fixed-target operations. For the past four years, the Tevatron has been dedicated to collider operations. In June, we will once again extract a beam of 800 GeV protons from the Tevatron, the highest-energy external beam in the world. By directing this beam onto eight stationary targets we will be able to create eight distinct varieties of particle beams that will in turn support 10 unique experiments.

Although fixed-target experiments cannot explore the high-energy frontier of particle physics the way the Tevatron collider experiments can, they can probe very precise questions about subtle, unexplained phenomena first discovered at lower energy. One such phenomenon is the mystery that our planet, our solar system, and indeed our galaxy appear to be composed almost entirely of matter—protons, neutrons, electrons and neutrinos—when our laws of particle physics are almost perfectly symmetric between matter and antimatter. Thirty-two years ago, the then-accepted laws of particle physics were not *almost* perfectly symmetric; they *were* perfectly symmetric. Then physicists working at Brookhaven National Laboratory detected a subtle effect in the decay of neutral K mesons. In turn, it was discovered that this was a consequence of a slight difference in the rate at which neutral K mesons containing a strange quark and their antimesons containing an antistrange quark decayed into other particles. Thirty-two years ago we couldn't describe the observed difference in decays of these mesons in terms of quarks and antiquarks, because quarks and antiquarks were still only speculations.

A group of scientists at Fermilab has been pursuing this slight difference between matter and antimatter by making ever more precise measurements of the decays of neutral K mesons. The Fermilab neutral K meson beam is the ideal tool for further refining these measurements. After four years of dedicated work, 80 scientists from 10 U.S. universities, one Japanese university, and Fermilab are just completing an elegant new detector, called KTeV, for this experiment. If they can make the measurements sufficiently precise, these scientists will provide the first new insight in 30 years into this mysterious asymmetry.

Measuring the differences between the decays of mesons containing strange quarks and antimesons containing antistrange quarks is not the only path to understanding the difference between matter and antimatter. The Stanford Linear Accelerator Center is building the B-Factory and the Babar detector to search for differences between decays of mesons containing b quarks and antimesons containing anti-b quarks. If our current understanding of the origin of these small differences between matter and antimatter is correct, the B factory approach may yield more information than the KTeV approach; but both experiments are needed. In the end, these different threads of data weave the fabric of advances in science.

I have described one of Fermilab's 10 upcoming fixed-target experiments. As we speak, Fermilab and university physicists, engineers, technicians, and graduate students are working feverishly to get ready to operate by July 1.

Collider Detectors

They aren't the only ones who are busy. Nearly 900 scientists, mostly from U.S. universities, are turning in earnest to the task of rebuilding the two collider detectors that were used to find the top. They are preparing for the day when the Main Injector makes it possible to deliver far more intense beams of antiprotons and protons. The rebuilt detectors will not only keep up with the new intensity but will detect these collisions more efficiently.

Main Injector

Meanwhile, the Main Injector remains on schedule for completion in 1999. A few weeks ago, we poured the last bucket of concrete for the two-and-a-quarter mile beam enclosure that will house Fermilab's newest particle accelerator. The project is on budget and will be completed within the total estimated cost of $229.6 million, on schedule in 1999—if the $52 million request for the Main Injector for FY1997 is enacted.

NuMI

If invited to testify again next year, I will want to tell you of a new project now in the planning stage, Neutrinos at the Main Injector. The intensity of the Main Injector's proton beam will allow us to design an intense beam of neutrinos to study another mystery in particle physics, the question of neutrino mass. Some 200 scientists have formed two experimental groups at Fermilab to plan how to send an intense beam of neutrinos to a detector deep underground in the Soudan iron mine in northern Minnesota, and to one at Fermilab to provide data that will help solve the neutrino mystery. Just as the top quark presents the dilemma of why it is so heavy, neutrinos raise the question of why they are so light or—perhaps—have no mass at all. Once more, experimental hints that neutrinos might have a tiny mass, around a millionth of the mass of the electron, give rise to speculation on their meaning for the grand scheme of things. Once more, the data will win out in the end.

We are not without problems.

While the proposed budget for facilities operation in FY1997, including the Scientific Facilities Initiative, is slightly less than the budget enacted in FY1996, we believe that it will allow 32 weeks of operation. In FY1997, we must accommodate nearly $5 million in additional costs from the increased use of electrical power and cryogens required for fixed-target operations. The average salary cost per employee will increase by somewhat more than three percent. In 1995 and 1996, we held the increase to much less than three percent. We will offset inflationary pressure on our payroll costs with another staff reduction. In the past two months, we have set in motion a plan to decrease the staff by an additional 75 between June 1, 1996 and January 31, 1997. Even if our funding stays constant in then-year dollars in the out years, we will have to continue to downsize by 75 people per year. Since 1992, we have reduced the staff from 2,400 to 2,100. With fewer people, we have had to make gradual reductions in our scientific program.

All or None

Although they are separate, Fermilab's accelerators are parts of a single scientific instrument; each is required for the whole to work. The Laboratory does not have the option of operating only some of the accelerators—it's an all-or-nothing proposition. If the President's FY1997 Budget Request is enacted, we will schedule 32 weeks of operation from October 1 through July 1, with interruptions only for maintenance. In July, we will suspend operations until the beginning of FY1998. 32 weeks of operation represent 80 percent of full operation of 40 weeks.

Support for the Budget Request

I want to close as I began, on a positive note. Throughout the past five decades, each Congress and Administration has supported high-energy physics. Initially this support made the U.S. the clear world leader. American scientists created the field of high-energy physics and gave it a distinctively American stamp. Today, we are still able to keep our place among the world leaders in this field. I want to make the case that research in fundamental science, such as elementary particle physics, is one mark of a nation that aspires to greatness. The search for an understanding of the origin of the universe, and of the origin and nature of matter are among the elements that make us human, and the quest for that knowledge is something that a great nation should pursue.

I support the Administration's FY1997 Budget Request. It is balanced between reaping the investment from existing facilities and making additional capital investment to proivde the capabilities that we desire three years from now. The nation's investment in high-energy physics has allowed researchers working at Fermilab, Brookhaven, and Stanford to make remarkable advances. As we look toward the year and the decade to come, we believe that more discoveries await us, if we have the resources to pursue them. I hope that we can continue to enjoy your support.

Chairman ROHRABACHER. Thank you, Dr. Peoples. Dr. Richter.

STATEMENT OF PROFESSOR BURTON RICHTER, DIRECTOR, STANFORD LINEAR ACCELERATOR CENTER, STANFORD, CALIFORNIA

Professor RICHTER. Mr. Chairman, I appreciate the opportunity to testify before this Committee. SLAC's research program is centered around electron accelerators and has two main thrusts—one in elementary particle physics and the other spanning many disciplines using synchrotron radiation.

We have a staff of about 1,400, 50 percent of whom are professionals. Of these, 150 are Ph.D's, including three Nobel Laureates and five members of the National Academy of Sciences. Most important, about 1,800 outside scientists use the facilities of the laboratory.

In our high energy physics program, we are carrying out experiments using our present accelerators while at the same time constructing a new facility, the B-factory. The largest of our current experiments uses the unique properties of our linear collider facility to do work that cannot be done elsewhere.

The program is highly productive. And, we plan to continue it to mid-1998 when the new B-factory is ready to turn on.

At that time, present budgetary projections indicate that we cannot operate both the old and the new. And, we will, with considerable regret for lost opportunities, terminate this program. Our experimental program is described in more detail in my written submission.

The B-factory now under construction is on schedule and on budget. The last installment of construction money, $45 million, is included in the 1997 budget. If approved, we will begin to commission the facility in FY-1998 and start scientific research early in FY-1999.

The experimental apparatus for the B-factory is being built by an international consortium, wherein the foreign partners are contributing elements of the detector valued at about 40 percent of the total detector cost. This is the largest foreign collaboration in the history of the U.S. program and is a testimonial to the scientific importance of the project.

Funding for our ongoing high energy physics operations in 1996 was somewhat less than in 1995. We will manage to operate our experimental program for eight months in FY-1996, although we have had to lay off approximately 70 of our staff.

In FY-1997, the DOE's projections, based on the President's budget submission, has operations funding less than in FY-1996. The operations for nine months, which we had planned for FY-1997, will be very difficult at this level and cannot be accomplished without further reductions in staff.

I note that in FY-1994, the year of the cancellation of the SSC, the high energy physics budget was about $1,300 million. When the SSC was cancelled, Congress asked the DOE for a long range plan for high energy physics, and that plan was presented in the spring of 1994 and was well received by this Committee.

It included a suggested budget plan for a viable program at levels much lower than in SSC days. Appropriations from Congress in FY-1995 and 1996 were quite close to those recommendations.

Sacrifices are surely necessary to balance the federal budget. But, I hope that Congress will note that the cut from $1,300 million in FY-1994 to present levels is already quite a sacrifice and that Congress will continue to come close to the suggested plan.

I want to say a word about our synchrotron radiation program as well. The synchrotron radiation program serves 900 of our users with 29 experimental stations and five more under construction.

Demand from the university laboratory and industrial communities far outstrips supply. Interestingly, the areas of most rapid growth and demand for beam time are in structural biology and in the environmental sciences. It is in these areas that the new experimental stations are now under construction.

The Facilities Initiative approved by Congress in 1996 has had a major impact on the synchrotron radiation operation. Operations in 1996 were up 33 percent from 1995. And, they will go up another 10 percent in FY-1997 at the proposed budget level.

Chairman ROHRABACHER. Dr. Richter, I have a vote on in International Relations, a markup. And, I am going to turn this over to Lindsey Graham for a moment, our Vice Chairman, who will then proceed as chairman for a few moments.

And, I will be right back. But, please continue.

Professor RICHTER. I am virtually finished. You have heard almost everything essential.

Chairman ROHRABACHER. Didn't I see a surfer going along, an electron, when I visited?

Professor RICHTER. I thought I sent you one of those pictures for your——

Chairman ROHRABACHER. You certainly did. It's in my office. Thank you.

That was before the gift ban, I want to note.

[Laughter.]

Professor RICHTER. It's under 10 bucks.

[Laughter.]

Professor RICHTER. Let's see. I shall go on. Increased operations in 1996 resulted in an increase in the number of users of the facility as well.

We expect them to be up 20 percent compared to previous years. And, our users are very happy with these opportunities.

In summary, Mr. Chairman, SLAC is a strong program in both high energy physics and synchrotron radiation. And, what is needed to keep the program moving forward at the frontier as a science is sufficient funding to operate the present facilities and to continue R&D that can lead to new opportunities in the future.

Thank you.

[The prepared statement of Mr. Richter follows:]

TESTIMONY AT A HEARING OF THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT COMMITTEE ON SCIENCE OF THE U.S. HOUSE OF REPRESENTATIVES

BY

PROFESSOR BURTON RICHTER, DIRECTOR
STANFORD LINEAR ACCELERATOR CENTER

May 8, 1996

INTRODUCTION

The Stanford Linear Accelerator Center (SLAC) is a national facility operated by Stanford University for the U.S. Department of Energy (DOE). SLAC has been in continuous use for thirty years in a national research program that has made major contributions to our understanding of nature. The Center is one of the handful of laboratories worldwide that use accelerators to advance the study of the structure of matter and the forces between the basic building blocks of our world.

The SLAC program is centered around electron accelerators and has two main thrusts: one is a program of experimental and theoretical research in elementary-particle physics, using electron beams; the other is a broad program of research in atomic and solid-state physics, chemistry, biology and medicine, using synchrotron radiation. Scientists from all over the country and from many foreign nations participate in these experimental programs. SLAC also has a very strong program in the development of accelerators and detectors for high-energy physics and synchrotron-radiation research, and has developed many techniques in these areas that are in use in laboratories all over the world.

SLAC was founded in 1962. A decade later the Stanford Synchrotron Radiation Laboratory (SSRL) came into being as a national users facility. SSRL became part of SLAC in 1992. The combined staff is currently about 1400, about 50% of whom are professionals. Of these professionals, 150 are Ph.D. physicists, including three Nobel Laureates and five members of the National Academy of Sciences. About 1800 scientists use the facilities of the laboratory for their work, about half in high-energy physics and half in synchrotron radiation.

THE HIGH-ENERGY PHYSICS PROGRAM

The SLAC high-energy physics program has three main thrusts. One is an experimental physics program aimed at uncovering the facts about the fundamental structure of matter. The second is a theoretical physics program that helps guide the experimental work and integrates it into models that help explain the behavior of things in our universe. The third is a program of accelerator physics that enhances the performance of our present accelerators and enables us to build the machines that are needed for the next generation of experiments. Currently we are engaged in an experimental program based on the high energy and unique beams of our present accelerator while at the same time constructing a new colliding-beam facility, the Asymmetric B-meson Factory.

The largest of our current experiments is the collaboration studying the properties of the Z-boson, the carrier of the so-called weak force. The experiment uses our linear collider facility, a unique colliding-beam facility wherein oppositely-directed beams of high-energy positrons and highly polarized electrons collide to produce polarized Z-bosons. The combination of high energy, polarization, and the extremely small size of the collision region makes it possible to do experiments and uncover information that cannot be accomplished elsewhere. This program is highly productive and we plan to continue it to mid-1998 when the new B-Factory is ready to turn on. At that time, present budgetary projections indicate that we cannot operate both and we will, with considerable regret for lost opportunities, terminate the Z-boson program.

The next largest of our current experiments uses the polarized electron beam of the linear collider to study the spin structures of the proton and neutron. Here too the unique properties of the beams and the high intensity of the accelerator make possible a unique contribution to physics.

There are also several other smaller experiments that I do not have time to go into here.

The new facility now under construction, the B-Factory, is aimed at the detailed study of a phenomenon called CP Violation which accounts for a small difference in the behavior of matter and antimatter, which seems to be a crucial ingredient in the formation of our universe. Without this difference the matter and antimatter that were present in equal amounts in the beginning would all have annihilated, leaving behind nothing but radiation and a universe empty of matter. Of course, it has not turned out that way and we do not understand why.

The B-Factory project is on schedule and on budget. Congress has approved funding for the project in Fiscal Years 1994, 1995 and 1996, in accord with the original plan. If, as we hope, Congress also approves the last $45 million installment included in the 1997 budget, we will begin to commission the facility in FY1998 and start scientific research early in FY1999.

The experimental apparatus for the B-Factory is being built by an international consortium wherein the foreign partners are contributing elements of the detector valued at about 40% of the total detector cost. This is the largest foreign collaboration in the history of the U.S. High Energy Physics Program, and is a testimonial to the scientific importance of the project.

The SLAC high-energy physics budget for Fiscal Year 1996 has been very tight. The B-Factory construction project reached the peak of its spending ($52 million) and funding for the detector project began to grow ($14 million). The result was a budget for on-going operation that was less than that of FY1995. In spite of this we have maintained operations for our experimental program at eight months in FY1996, although we have had to lay off approximately 70 of our staff.

For FY1997, we do not yet know what the Congress will approve. The DOE has given us an estimated allocation based on the President's budget submission that has funding for our on-going operations less than in FY1996. Our first priority must be the new accelerator now under construction and its detector. Operations for the nine months now planned for FY1997 will be very difficult at the President's budget level, and cannot be accomplished without further reductions in staff.

I note that the physics budget in FY1994, the year of the cancellation of the SSC, was about $1300 million. At the time that the SSC was canceled, Congress asked the DOE for a long-range plan for high-energy physics. That plan was forthcoming in the spring of 1994 (Drell Subpanel of the High Energy Physics Advisory Panel) and included a budget plan for a viable program at a much lower level than in SSC days. The total of Congressional appropriations in FY1995 and 1996 are quite close to that recommendation. If the plan was to be followed into FY1997, a budget of $710 million would be required. While we all recognize that sacrifices are necessary to balance the Federal budget, I hope that Congress will note that a cut from $1300 million in FY1994 to $710 million in FY1997 is already quite a sacrifice.

SYNCHROTRON RADIATION

What is now SSRL began in 1972 as a parasitic operation on the then-new electron-positron colliding-beam storage ring that I had built for high-energy physics research. I still remember installing outside of the machine shield wall a nine-foot by twelve-foot garden shed that we had bought from Sears to house the first experiment. The x-ray beams available at SPEAR were about one-million times the intensity of those available from x-ray tubes, and the first experiments demonstrated a revolutionary capability. The field has grown rapidly since then, not only in the U.S., but around the world.

The SSRL facility is now one of four DOE synchrotron radiation sources in the United States. SSRL's beam energy of 3 GeV allows it to deliver better hard x-ray beams than those available at the National Synchrotron Light Source at Brookhaven, or the Advanced Light Source at Lawrence Berkeley Laboratory. Although the newly completed Advanced Photon Source at Argonne National Laboratory has a higher energy, the SSRL machine delivers comparable intensities in the very important 10-15 kV x-ray region, though the beams from the APS are much brighter. Each of the four machines in the U.S. has a unique role to play in the DOE's program.

SSRL currently has 29 experimental stations, of which 20 can be operated simultaneously. Five more experimental stations are under construction. Almost all of these are available to the general user community through proposals submitted to peer review panels. This is a somewhat different mode of operation from that of other laboratories wherein specialized collaborations with long-range programs use a large fraction of the available time. SSRL's location in Silicon Valley is very important to the high tech companies in the area. Demand for beam time from the university, laboratory and industrial communities far outstrips supply.

SSRL has built up special instrumentation and staffs that give it singular strengths. It is very strong in protein crystallography, x-ray absorption spectroscopy, and surface x-ray scattering. It is also excellent in x-ray topography and the structure of amorphous materials. The protein crystallography and x-ray absorption spectroscopy capabilities are in high demand among the approximately 50 structural biology and specialized pharmaceutical design groups in the West. The surface x-ray scattering and x-ray topography capabilities are important to the semiconductor industry, while soft x-ray absorption spectroscopy is important for magnetic information storage materials.

The areas of most rapid growth in demand for beam time are in structural biology and in environmental sciences. It is these areas that the new experimental stations now under constructions are targeted.

The Facilities Initiative approved by Congress in FY1996 has had a major impact on SSRL's operations. In FY1995, total funding (excluding construction of new beam lines) was $16.8 million which jumped to $21.6 million in FY1996. At the President's proposed budget level for FY1997, DOE estimates SSRL funding for on-going activities to be $23.9 million. This has had a major impact on the user community. In FY1995, total running time was approximately 30 weeks. This jumped by ten weeks in FY1996, and is projected to jump up by another four weeks in FY1997 at the President's budget level. If all goes as planned, we expect the number of users who receive beam time to increase by nearly 20% in FY1996 compared to FY1995. The user community is very happy with the increased operations.

SUMMARY

SLAC has very strong programs in both high-energy physics and synchrotron-radiation research. The combination of first-class experimenters, first-class theorists, and first-class accelerator builders in one laboratory has led to the development of facilities in programs of great benefit to the broad user community in the United States. About 1800 of those users were involved in the program last year, and we expect the numbers to increase somewhat in the years ahead. What is needed to keep the program moving forward at the frontiers of science is sufficient funding to operate the present facilities and to continue R&D that can lead to new opportunities in the future.

Mr. GRAHAM (Presiding). Thank you very much. Dr. Samios.

STATEMENT OF DR. NICHOLAS P. SAMIOS, DIRECTOR, BROOKHAVEN NATIONAL LABORATORY, UPTON, NEW YORK

Dr. SAMIOS. Again, thank you for having me testify before this Committee. Brookhaven National Lab gets 80 percent of its funding from the Office of Energy Research, so we are a major player.

To be succinct, I would say the Scientific Facilities Initiative was absolutely crucial for our facilities in the last year. We are in the position of having facilities in high energy, nuclear and basic energy sciences.

So, I will step through briefly each of these. In the case of our High Flux Beam Reactor, which Mr. Wamp and Martha Krebs mentioned before, the Facilities Initiative enabled us to double the running time in Fiscal 1996.

If we had the same funding in 1995, we would have had half the running time. That was a substantial effect on our program. To remind you, this facility has roughly 300 users from 46 universities and 14 U.S. industries.

With the National Synchrotron Light Source, which produces intense x-rays and radiation, again the Facilities Initiative had a substantial effect. This leading facility operates 85 simultaneous beamlines with over 2,200 users, representing 132 universities, 28 labs, 56 industries and so on.

The Facilities Initiative enabled us to increase our operating time by 13 percent. But, even more, it added staff which greatly helped utilizing the facility for our users.

The third major facility is the Alternating Gradient Synchrotron which provides intense beams of protons and heavy ions. In the nuclear physics domain, the funding again essentially doubled the amount of running time that we would have had otherwise.

In the high energy end, the situation wasn't as dramatic. Actually, we reduced line time. But, I've been led to believe without the Facilities Initiative we would have even had less running time.

I have a special appeal in the nuclear physics area with CEBAF facility, which is your next coming on line, and the RHIC facility, which we are presently building to come on line in 1999. The funding level for nuclear physics needs to be restored to its historical values and the push in 1996 is a great step in that direction.

I would just like to make a few comments now on the overall funding in the biomed area. This is an area where the funding is going down because construction projects are coming to an end.

It would be tremendously useful if some of that money could be retained to enhance the scientific capabilities i these areas. In our area, we have particularly two programs which are outstanding, which have an affect on human health.

One is in treating glioblastomas, which is going through patient trials, which could use slightly more funding; and, the second has to do with nuclear imaging, where we have a new MRI and again having great advances having to do with smoking and brain function. And, so using some of that money, retaining some of that money, to be pumped into biomed, I think, would be a worthwhile endeavor.

So, I would conclude by saying that the Scientific Facilities Initiative is important and cost effective for increasing first-class science output. The general budget for Energy Research is tight.

I understand the desire is to reduce government spending. I would ask that the effects of the cuts be carefully weighed before being imposed.

The DOE Laboratory System is the envy of all scientific institutions throughout the world. It is robust and when adequately funded can become—but when not adequately funded, it can be dangerously fragile.

I strongly support the proposed budget proposed by the Administration. Thank you.

[The prepared statement of Dr. Samios follows:]

Testimony of Nicholas P. Samios
Director, Brookhaven National Laboratory
before the Hearing of the
Subcommittee on Energy and Environment of the
Committee on Science

Wednesday, May 8, 1996

Mr. Chairman and Members of the Subcommittee, I am pleased to have the opportunity to testify and share my views on the Scientific Facilities Initiative and the budget request for the Department of Energy's Office of Energy Research (OER). As the Director of Brookhaven National Laboratory I have a strong interest in these two topics since our lab received about 80% of its funding from OER and has major user research facilities in the high energy, nuclear and basic energy sciences. As a general comment, I would like to point out that Energy Research in DOE is the leading supporter of basic research in the physical sciences. The triad of Energy Research, the National Science Foundation and the National Institutes of Health are our nations key sponsors of basic scientific research

The Scientific Facilities Initiative was an excellent idea to increase the utilization of existing facilities in the energy research area. It was recognized that when one has existing facilities, small increases in funding lead to large increases in operations. That large leverage factor made the Initiative extremely cost effective since one must continue to pay the base salaries of the talented and highly trained personnel necessary for the operations, even when one is not running the facilities. It is not an option to only hire those people just for the months in which the facilities are running. This increase in running time at the facilities helps decrease the backlog of approved peer review experiments.

One of our facilities that was strongly affected by this initiative was the High Flux Beam Reactor (HFBR), a reactor designed to produce high intensity neutron beams for research in materials science, chemical science and biological science. In fiscal 1995 we had 277 users representing 46 US universities, 9 US labs, 14 US industries and 40 non-US organizations utilizing the HFBR. If we had the 1995 funding level in fiscal year 1996 we would have been able only to run 133 days. With the incremental funding that we did receive we are scheduled to run 270 days and we are on target with this schedule and will carry out approximately 300 experiments this year.

Another facility that was affected was our National Synchrotron Light Source (NSLS) which produces intense x-rays and uv radiation for the materials, chemical, biological and medical science communities. This facility comprises a total of 85 beamlines which, in 1995, served 2200 users representing 132 US universities, 28 US labs, 56 US industries and 126 non-US organizations. During the first quarter of this fiscal year we have been able to increase the operation of this facility by 13% and have provided a total of 104,000 station-hours to the user community. In other words, we have provided an additional 10,000 station-hours during this first quarter. We have also added 6 staff members to assist the experimental team utilizing the beamlines.

Our third major user facility is the Alternating Gradient Synchrotron which provides intense beams of protons and heavy ions. This facility is funded by high energy physics when running protons and by nuclear physics when running heavy ions. The total user community for both programs is about 900 scientists from 8 labs and about 110 university groups both from the US and abroad. The incremental funding has a dramatic effect on the nuclear physics utilization. The running time was increased from 4 weeks in fiscal 1995 to a planned total of 12 weeks in fiscal 1996, with 8 of these weeks at the same energy as the 1995 running and 4 weeks at a lower energy. The research teams are now able to get much needed data with this running schedule. With CEBAF now on-line and soon RHIC, the funding level for nuclear physics needs to be restored to its historical values. This request for an increase in 1997 over the 1996 budget is a step in the right direction. Unfortunately we did not see an improvement in the high energy running schedule. We are only funded to run 12 weeks or possibly 16 weeks in this fiscal year, as compared to 25 weeks in the previous fiscal year. This will be a hardship for the high energy experimentalists who have built their equipment and are on the floor of the accelerator.

With the exception of the high energy program we have seen a dramatic improvement on the utilization of our scientific facilities. I strongly support the Scientific Facilities Initiative. We have a large capital investment in these facilities and we have a vigorous first class peer reviewed scientific program which helps us more fully exploit the rich opportunities in these fields with small incremental funding.

I would now like to make a few comments on the overall funding for the Office of Energy Research. In most cases, the proposed budget allows us to continue our efforts with some belt tightening. At our lab we have had to reduce staffing levels during both previous years, a situation not uncommon to the other DOE labs. Top notch research teams take years to assemble. Once dispersed it becomes difficult to reassemble teams. When a program is judged to be nonproductive one supports the termination of those efforts. What is of concern is the whittling away of highly rated programs by a series of small cuts. We must fund those programs at a level that ensures the necessary sustained effort.

One area of energy research that has been hit hard in this proposed budget is that of the Office of Health and Environmental Research (OHER) in OER. This has occurred as a result of the ending of several construction projects in this area. It is normal to decrease the budget in that event, but it also provides an opportunity to save part of the reduction to improve the operating research budgets of those programs, which are hard pressed. In our laboratory we have tight fiscal problems in several programs in this area of energy research which are very highly rated. One is the work on boron neutron capture therapy where we have extremely encouraging results on the treatment of a form of a deadly brain cancer. The treatment consists of giving a patient a boron compound that selectively goes to the tumor and then exposing the patient to a beam of neutrons from our medical reactor. We have successfully moved from phase I trials into phase II trials. Despite the great promise we are very short of operating funds. In our brain imaging center we have just obtained a new magnetic resonance imaging machine with a high magnetic field which will complement our PET and SPECT imaging machines. Despite many exciting results, like the recent connection between smoking and brain function, we are again very short of operating funds for this program. If some of the reduction in the funding for that entire area in energy research could be rescinded, the operating budget could be partially increased. There are many parts in the DOE laboratory system in a similar situation to Brookhaven where that small increase in operating funds would have a large impact on their programs.

In summary, the Scientific Facility Initiative is important and cost effective for increasing first class science output. The general budget for energy research is tight. I understand the desires to reduce government spending. I would ask that the effects of cuts be carefully weighed before being imposed. The DOE laboratory system is the envy of all scientific institutions throughout the world. It is robust when adequately funded but can become dangerously fragile if steadily cut back. I support the proposed budget as a minimal level for science.

Mr. GRAHAM. Thank you, Doctor. Dr. Grunder.

STATEMENT OF DR. HERMANN GRUNDER, DIRECTOR, THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY, NEWPORT NEWS, VIRGINIA

Dr. GRUNDER. Mr. Chairman and distinguished members of the Subcommittee, I appreciate the opportunity to testify before you today. CEBAF and its users are part of the scientific facilities which lays the foundation in knowledge on which future technologies will be developed.

First, let me thank you and the U.S. Congress for its support of fundamental science in these hard times. We appreciate your support and we commit ourselves to give you the best value in return we can do.

CEBAF has just come on line less than a year ago and so far has met, even exceeded, the expectation of our users. CEBAF provides unique capabilities not duplicated elsewhere in the world.

The Scientific Facilities Initiative has enabled us to run two-thirds of the time available in FY-1996. And, it is hard for me to imagine FY-1996 without this initiative.

To the extent that the funds for the Scientific Facilities Initiative are not taken away from our users, I fully support the initiative and hope that it continues.

Nuclear physics experiences an amazing rejuvenation with two major facilities coming on line—CEBAF, as just mentioned, and Relativistic Heavy Ion Collider that you just heard about becoming the centerpieces of our field. The community recognizes the opportunities the U.S. government has provided and declared as the highest priority in its 1995 long range plan is the "vigorous pursuit of the scientific opportunities provided by the nation's recent investments in forefront instrumentation and facilities."

I support the FY-1997 President's budget as it pertains to general science and energy research. The FY-1997 budget also contains outyear projections, which have been discussed at this hearing a moment ago.

I would like to register real concern on the precipitous top of the FY-1998 budget in DOE ER, in general, and general science specifically. I fail to understand why ER is not treated similar to NIH and NSF as an important part of the scientific support for the nation.

I am particularly concerned at the negative feedback the Administration's FY-1998 budget could have on the FY-1997 congressional appropriations. I, therefore, would like to urge the Administration to clarify its positions with respect to fundamental research and include the Department of Energy Research among its high priorities like NSF and NIH.

Thank you for your time.

[The prepared statement of Dr. Grunder follows:]

Testimony of
Hermann A. Grunder, Director
Continuous Electron Beam Accelerator Facility (CEBAF) *
before the
Subcommittee on Energy and Environment
of the
U.S. House of Representatives Committee on Science
regarding the
Department of Energy Office of Energy Research Programs
and the Scientific Facilities Initiative

May 8, 1996

Chairman Rohrabacher and distinguished members of the subcommittee: I am Hermann A. Grunder, Director of the Continuous Electron Beam Accelerator Facility (CEBAF), the Department of Energy's newest laboratory for research at the forefront of nuclear physics. I am honored that you have asked me to provide my perspective on the FY97 budget as it relates to DOE's Office of Energy Research programs at CEBAF and on the Scientific Facilities Initiative. I welcome the opportunity to share with you both the exciting opportunities and the challenges facing CEBAF and the Nuclear Physics community.

CEBAF is a research facility designed to deepen our understanding of the fundamental nature of nuclear matter. Its centerpiece is a superconducting radiofrequency recirculating accelerator that can provide precise electron beams of various energies to three experimental halls simultaneously. CEBAF's construction has been completed on cost and schedule and DOE has formally accepted us into its family of scientific user facilities. Though we have just begun our research program, the demand to use our facility is enormous. Already six years of experimental time has been allocated for the user community of over a thousand scientists worldwide. The unique capabilities of this facility make it the only place in the world where certain important experiments can be done.

This frontier would not have been accessible without the foresight and investment of the federal government. You recognized the need to maintain the United States' leadership position in nuclear physics and fulfilled that need by providing support to build

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* Government-owned, contractor-operated in Newport News, Virginia for the U.S. Department of Energy by the Southeastern Universities Research Association (SURA)

and operate CEBAF as an important part of the nation's fundamental science portfolio. Despite serious fiscal stringencies, the U.S. government has consistently provided the resources necessary to continue to advance our understanding of nuclear matter in terms of its basic constituents. For that support the community is extremely grateful. I would be personally remiss if I missed this opportunity to thank Congress for all it has done to build and support CEBAF and the rest of Nuclear Physics.

We are committed in this era of deficit reduction to give the taxpayers the best possible science return for their dollar. Therefore, during the past two years we have been working hard with the Department of Energy to implement a performance-based contract, and to streamline our operations while maintaining high standards of excellence in all areas. We have embraced performance metrics adopted by the Office of Energy Research, and I am proud to report that CEBAF is at or near the top in performance within the Office of Energy Research.

The Renaissance of Nuclear Physics

This is an exciting time in Nuclear Physics. The nuclear physics community has, in the past few years, enjoyed a rebirth of ideas and an expansion of its scientific goals. It was this very "renaissance" that led to the federal government's support of a coherent research program that provided two new major complementary facilities that are now coming on line — CEBAF, and soon the Relativistic Heavy Ion Collider (RHIC). These facilities will explore fundamental questions that are at the core of our understanding of the world around us. RHIC is now in the final stages of construction, and CEBAF, as an operating laboratory, is the envy of the worldwide nuclear physics community. The community has prepared a Long Range Plan to take advantage of these new capabilities. Its highest priority is the "vigorous pursuit of the scientific opportunities provided by the nation's recent investments in forefront instrumentation and facilities." This emphasis on running existing facilities is completely aligned with the intent of the Scientific Facilities Initiative.

The building of current Nuclear Physics capabilities has not been without pain. A number of tough choices had to be made including the shutdown of the Bevalac in Berkeley, termination of nuclear physics at LAMPF at Los Alamos National Laboratory, and closure of five smaller NSF-supported university facilities. Budgets provided between 1991 and 1997 have resulted in an overall program downsizing totaling 30%. The result, however, is a lean, scientifically aggressive program that guarantees world leadership in this important area of research while optimizing return on the investment the nation has made in these endeavors.

Importance of the Scientific Facilities Initiative

The federal government has recognized as very important the role of the Office of Energy Research function to provide unique civilian research facilities. These facilities and the capabilities they provide are the centerpiece of civilian research programs in High Energy Physics, Nuclear Physics, Basic Energy Sciences and many other disciplines.

The Scientific Facilities Initiative (SFI), begun in 1996, validates and enables this critical function of the Office of Energy Research. By funding effective utilization of existing facilities, the SFI provides a large leverage factor on our R&D dollars, thereby increasing the scientific output. In Nuclear Physics, the National Science Foundation and the U.S. Department of Energy each fund about half of the university user population at these national scientific facilities. The Scientific Facilities Initiative provides complementary funding that allows the facilities to run for much of the year without taking resources needed by the users to prepare for and perform the experiments planned for these facilities.

For CEBAF, this initiative meant that we were able to run for physics experiments at about 70% of our full utilization and could deliver our first physics results. Without the SFI, we may not have been able to provide beam for experiments at all in this, our first critical year of operations.

Funding Realities for Nuclear Physics

While the FY97 funding requested in the President's Budget provides for enhanced operating time above earlier projections, the community is faced with very real concerns regarding the overall health of the nuclear physics program. The pressures are predominantly the result of a decline in nuclear physics funding coupled with the size and complexity of the two new facilities and their experimental programs.

Though I understand that the purpose of this hearing is to discuss the FY97 budget, I hope you will allow me to speak to a related issue that causes me much concern. The FY97 budget is tight, however the community can make adjustments in order to sustain a viable program in any one tough year. However, I understand that the Administration's current outyear projections beginning in FY 1998 for the Office of Energy Research project rather dramatic cuts, necessitating a reprioritization of U.S. nuclear physics research that would sacrifice a substantial portion of the current program. The Office of Energy Research is an important sponsor, along with NSF and others, of basic research in this country. It is vital that a balanced, rational and consistent plan be developed for federally-funded fundamental research programs sponsored by DOE, NSF, and others. In order to remain at the cutting edge, the Nuclear Physics community and the larger scientific community need a funding profile that allows for responsible planning in order to accomplish the best and most important science. Both facilities operation and users research need to be adequately funded for the U.S. to continue to pursue excellent science. A multi-year erosion of funding without an adjustment in scope seriously jeopardizes our scientific preeminence. Underfunding and uncertainty are enemies of optimized scientific output. I am hopeful that corrective action will be taken to avoid a serious setback for Nuclear Physics and other important scientific research programs.

I would like to repeat my support for the Administration's nuclear physics budget for 1997. While we could do more science with more funding, the budget, particularly the DOE budget, will allow a reasonable level of operations. I would ask you to note, however, that the nature of complex facilities such as CEBAF means that even modest incremental reductions in our budget (at the level of 5%) can have a major impact, reducing the utilization drastically.

The United States government has made an investment to build and maintain scientific facilities and infrastructure that are the envy of the world. The Scientific Facilities Initiative, along with the efforts to make the laboratories more effective and their relationship with DOE more efficient can make it possible for us to maintain a level of scientific excellence and leadership that will take us into the twenty-first century. By providing a consistent funding profile for our nation's scientific enterprise, we send a signal to bright young people that we see fundamental research as important and as a worthy investment and pursuit for our future.

Mr. GRAHAM. Thank you, Doctor. I will tell you what, Mr. Roemer, would you like to lead off the questioning?

Mr. ROEMER. Yes. Thank you, Mr. Lindsey Graham, for letting me lead off with Mr. Rohrabacher probably back in his office looking at the surfer gift, making sure it was under $10, that you gave to him from Stanford.

[Laughter.]

Mr. ROEMER. Let me ask, first of all, in terms of the House-passed Energy Authorization from October of last year, that cut energy and nuclear physics funding from a little bit over $1 billion and the President's request down to about $950 million. What would this funding level mean for the activities funded under the high energy and nuclear physics accounts?

Dr. PEOPLES. I will start, and I will speak just a bit about the high energy accounts. My recollection is that the effect was to reduce the high energy physics budget request by about $20 million.

That, at Fermilab, meant that we slowed down substantially in the construction of the new collider detectors or rather the rebuilding of these detectors, because they were already in use. The rebuilding of these big, modern detectors takes four or five years.

So, that has been slowed down. We elected to put most of our emphasis, because of the Scientific Facilities Initiative, in operating and less in rebuilding. So, the affect was on slowing down the future.

Professor RICHTER. I understood the question to be about 1997, if that was cut to $950 million. That's a five percent reduction.

I think all our laboratories are operating on the edge right now. All of us have had long term reductions in our budget at SLAC. And, purchasing power has gone down by more than 30 percent since 1990.

We've kept machines running, but we have really wrung all the fat out of the place. And, we are now beginning to lose bone mass, not just fat.

I would have to take a really hard look at some very unpleasant choices with the loss of 5 percent of the budget. How we should balance this between staff reductions, eliminating elements of the program and cutting back on running time is something I really haven't faced. And, I very much hope I don't have to face.

But, we will do it if we have to. It's going to hurt.

Dr. SAMIOS. Let me comment on the nuclear physics part. It would have a very disastrous effect, in the sense that there are two facilities that have just been built or being finished.

And, at the budget level that exists for nuclear, the rest of the program is really very, very, very tight. If one had reductions, one either would have to eliminate parts of the nuclear physics program, slow down the construction of RHIC or not operate CEBAF as it should be operated as a new facility. So, the choices are very difficult.

I think nuclear physics has been responsible in the years. They have had a long range plan and, in fact, have closed many facilities in the past. And, the budget level is just at the minimum of the plan. So, there are Draconian choices.

I would second Burt's comments, in the sense that each of our labs have reduced staff in the last years. For instance, in the last two years, we've reduced 200 people, many in the support areas just to take up the inflation rate of the flat dollars.

Again, I would say if the cuts are larger, then more Draconian measures would have to be taken.

Dr. GRUNDER. The only thing I cannot—we will continue to lose a part of nuclear physics. We have lost some already up to now, and we will lose more.

What I think would be very important is to comment to some equilibrium situation, which the Administration and U.S. Congress can agree on, that we can plan, because the danger is that one would distribute a cut, as we call it, peanut butter and that would really drive the field to mediocrity. That should be, under all circumstances, avoided.

Mr. ROEMER. Thank you. Finally, Dr. Samios, could you give us your impressions of recent reports that have alleged that there has been some recent contamination that has escaped out of Brookhaven?

Can you bring some——

Dr. SAMIOS. Sure.

Mr. ROEMER. (continuing) —light to this allegation?

Dr. SAMIOS. Yes.

Mr. ROEMER. And, how has that affected further research at Brookhaven?

Dr. SAMIOS. What you are referring to is on our southern boundary, we've been looking—we have had a constant water monitoring program at the lab sinking wells. We have probably sunk over 400 or 500 wells at the site.

And, to go back a little, about four or five years ago, some contamination of TCEs was found in the neighborhood. Then, that was found by Suffolk County.

And, that was caused by an industrial outfit between us and that community. Okay?

We've constantly been surveying and sinking shallow wells, shallow wells about 100 to 140 feet, and saw nothing. Very recently, we have been sinking wells at 300 feet and we found some quantities of solvents, trichloroethylene. And, so we are investigating that and we are planning remedial measures.

As a—and these TCEs, from our understanding, in the groundwater contamination—I'm probably telling more than you want to know, but I've been propped up for this thing. I've answered this question several times.

We believe that we are not the person who is contaminating our southern site. Nevertheless, Suffolk County did a survey of 400 homes and found five homes with higher levels of drinking water standards of TCEs.

We believe, and Suffolk County believes, that they were caused by the industrial person between us. Nevertheless, there is a general apprehension on Long Island, and DOE and the Lab decided to hook up all these 400 homes with public water instead of their well water.

The community became somewhat concerned, because their feeling was if you are not doing anything bad, why are you spending several million dollars hooking us to public water. And, so we've been communicating with our community groups explaining what's going on.

But, as far as that is concerned, I think the factors are as I told you. And, Suffolk County agrees with that.

But, there is concern. And, we are handling it.

Mr. ROEMER. It sounds like you are going to continue to answer the question for awhile, too.

Dr. SAMIOS. Yes. This is the thing that—one of the key issues is how safe is safe.

You can get experts—and these are parts per billion, okay. And, you know, it's—but then how do you explain to a person if you measure something that it's safe to drink or not to drink.

And, that is a public perception problem. And, that occurs across this country.

Mr. ROEMER. Thank you.

Mr. GRAHAM. Thank you. It sounds like a good argument for risk assessment.

Mr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman. I certainly agree with your last comment about the need for risk assessment, because I'm sure it would be interesting to find out how many of the people living in those 400 homes are smoking or engaged in other endangering activities.

Just a comment and then a question for all of you. The comment is that in spite of the fact that you are sitting there and sounding upbeat and reporting wonderful results and saying the President's budget looks good, it doesn't look that good to me.

And, the Congressional budget isn't going to look any better. When you analyze what's happened to your budget over the past few years—and I believe, Dr. Richter, you were the one that pointed out that it went—in this area, it went down from $1,300 million to about $700 million. That's a huge cut. That's a real cut.

When you look at the total budget for the Office of Energy Research, it's less than 1 percent of the amount of money that this nation spends simply on Medicare and Medicaid. And, that, I think, is the heart of the problem we have here.

The entitlements spending, as we call it, has grown so large that the domestic discretionary spending, including your budget, is getting cut. It's getting squeezed steadily.

And, the pressure is going to increase in the years ahead, because any thinking individual looking at what is happening to entitlements spending is going to recognize what's going to happen. I find it depressing.

And, I think it's incumbent upon you, as scientists, to do a better job of making your case with the public. It might also help if you can educate the public about what entitlements mean and why the problem exists and, in particular, try to explain in simple arithmetic, which is all it is, why the problem is there.

I find that many of the people in my district are quite willing to consider reductions in Social Security COLA increases and things of this sort when they are made aware of the problem and made aware of the dimensions of the problem and the impact on their children and grandchildren. But, we have a long ways to go.

As you can see, with the Medicare issue, which we tried to tackle last year with I thought a very modest proposal and a very well thought out proposal, a very responsible proposal, and frankly we were being crucified by the other party with a slogan that we are cutting Medicare to provide tax cuts for the rich. It's totally unsubstantiated.

But, if we cannot win that minor battle, there's not much hope for dealing with the broader issues of the other entitlements, which are much larger and are much more serious problems. That's the end of my editorial comment.

But, I hope that, as scientists, you can help through your personal efforts, through your laboratory employees, just help educate the public to the dimensions of the problem and what's happening to our scientific research. I would also point out that since so much of the research, even though you are in esoteric fields of physics, a lot of your research does have bearing on medical costs.

And, with good application of your research we have a possibility of reducing some medical costs in the future. And, I think you could make a fairly good case that just within the field of medicine your research is cost effective. And, obviously it has bearing on a lot of other areas as well.

My question is much more pragmatic and direct. We had the Galvin report last year. And, the question is. To what extent has that been implemented within your laboratories and what have the results been?

Let's start with Dr. Peoples.

Dr. PEOPLES. The major thing that we have done in the past year is to—with the Department of Energy to reexamine how we manage environment safety and health. And, we have developed what is called the necessary and sufficient conditions.

This is a pilot program that the DOE started. It required a modification to the management and operating contract that URA has with DOE.

And, we have managed to restructure our ES&H quite a bit. We have not had any immediate financial gains, but we expect to have modest gains in the near future.

We are certainly making the organization smaller. And, we have a better understanding of what we have to do and remain in abidance with the law, which is the most important thing because we are sort of on our own now, which we welcome.

Mr. EHLERS. May I add one more dimension to the question? One of the charges of the Galvin report is that Congress is micromanaging DOE; DOE is micromanaging the labs.

Has that situation improved at all?

Dr. PEOPLES. Well, in regard to the ES&H thing that we are doing now, there is an improvement but we don't know whether you know about it. All right.

And, in other places, in some business practices, we think there is room for some improvement. But, we haven't seen the heavy yoke removed.

I mean, there's still an urge on the part of Congress to write a law that has hidden consequences. That is what you would call, and I would call, micromanaging.

I can't give you a specific example at this time.

Mr. EHLERS. And, I will continue to fight that and work with you on that.

Dr. PEOPLES. I am thankful.

Mr. EHLERS. But, time is expiring. But, quickly to the rest of the Directors.

Professor RICHTER. Well, with the Galvin report, I started to work with one of the company's in Silicon Valley to take a look at our administrative costs in the laboratory—what were our processes costing us. That has resulted in a tuneup of our administrative systems with some cost savings.

And, the analysis showed that actually the place that was most anomalous with respect to industry was this whole question of environment, safety and health where the costs in a DOE laboratory are far higher than they would be in an industrial environment. I think that the costs in any government facility in this area are going to be higher than in—let me call it—the civilian economy just because all government-funded facilities live in a kind of gold fish bowl. And, they have to be better than average.

DOE's environment, safety and health record is, in fact, better than industrial averages. But, it still costs us a huge amount of money to carry out all the studies, the reports, et cetera.

A lot of that is mandated by Congress. And, Congress could do a lot to ease the burdens on all of the laboratories and let us run more efficiently.

Mr. EHLERS. Thank you. Dr. Samios.

Dr. SAMIOS. I will be brief. I think the number of audits and reviews by DOE have been reduced. It has been a conscious effort to do that.

And, we see that, both in the non-scientific areas. So, I think there is an effort on the DOE to do that.

Internally, we have—as I mentioned earlier, we've looked at our overhead functions over the last two years. And, we've reduced the cost of our overhead functions.

We've had to do that to make ourselves more efficient. So, we are doing internal things.

But, the micromanagement level is still high. I don't know what you do about it, but it's still there.

Dr. GRUNDER. There is some improvement, no doubt. There are also some real good potential initiatives which could result in some cost saving.

We have a long way to go.

Mr. EHLERS. Thank you.

Mr. GRAHAM. Thank you. I will follow up on a comment you just made.

I know one thing we could do, is maybe abolish the Department of Energy. I don't know if that's a good or bad idea, but a lot of people are talking about it.

Could you comment right quickly? If that event occurred, and it may be in our House budget to do that, how would you function; and, would life continue to exist; and, how would that life be if the Department of Energy as a federal Cabinet level was abolished?

Professor RICHTER. I guess I am the brave one that will go first on that one. I think it depends on what you do.

I don't think the Department of Energy should be abolished. I think there's a good case for it.

That's a different question. You have asked what happens if it's done.

It seems to me that the Energy Research Science programs broadly are important for the nation. If you are going to simply reduce the Department of Energy from a Cabinet level to a non-Cabinet level organization, it won't matter a bit. If you really break up the Department in pieces, you have to really look at what you do with the research function and you have to put it someplace where other research functions are clustered so that you've got a somewhat coherent and efficient operation.

Dr. PEOPLES. I will add to that. In all of the plans that people have put forward, I have not seen where the basic energy research functions of the Department of Energy go.

They would have to go in a place where they could flourish. Many of the suggestions look like casting seed upon the stones—they are not going to flourish.

I'm not in support of an idea to abolish the Department of Energy partly because I don't see how these large facilities, which are so essential for research in the physical sciences, are going to be operated in the future.

Dr. SAMIOS. It depends on what you do. I think we flourished very well under the Atomic Energy Commission. The AEC was an agency, not a department. We did very, very well.

I will also reiterate what has been said here many times. Once you appreciate the research function of ER/DOE, the $2.5 billion, it should be on the same rank as NSF and NIH.

It's a major contributor to the basic research function of the country. And, it has got to be preserved whatever one does.

Dr. GRUNDER. There are many ways how you can organize a research establishment. I believe that a number of agencies, several cultures of how to fund basic research, is probably in our society a good idea.

And, in that sense, one should strive to have a congressional look at science in its totality. But, the administration of it would probably profit from it from having two or three access points and interaction with the practitioners.

Chairman ROHRABACHER. Thank you very much. I am going to recognize Ms. Jackson-Lee now. And, I do have one or two questions of my own when we are done with the Committee.

Ms. JACKSON-LEE. Mr. Chairman, you may go ahead, if you so desire.

Chairman ROHRABACHER. No. Go right ahead.

Ms. JACKSON-LEE. All right. Thank you, Mr. Chairman, for your kindness.

And, let me apologize to the panelists. I was detained because of other requirements of those of us who are in this business of representation of dealing with legislation in another location.

And, so I appreciate having the opportunity to comment. Let me be the other side of the coin and suggest, since the Department of Energy is an agency that as a practicing attorney that I practiced before some years ago, I would offer to say that we can make a better Department of Energy but we would not do well to eliminate an agency that has a very pointed focus on energy and research and certainly some of the concerns that we are facing today. I know that the second panel will certainly respond to the highlight of the day which is, over the period of time, the big debate on gasoline prices at the pump and particularly I think the energy supply research and development arm of your work, of the Office of Energy Research, may have a big, big role and maybe a more important role than we have offered to it to begin to stop having us go through these unending cycles of up today/down tomorrow, though we recognize a lot of it does play into the marketplace.

So, I would beg to differ with my colleague and friend and offer to say that the Department of Energy has some vital and important responsibilities. And, we must see how it can handle those responsibilities in the most efficient and effective way possible.

However, another call of the day, of course, is the work that the panelists are engaged in primarily because of the turn of this nation, appropriately so, to the need for high tech technology. And, the ability of science, as I will always say, is the work of the 21st century.

In the 19th and 20th, we built with our hands, less so at the end of the 20th. We have become more of a consumer service oriented nation. That frightens me.

I want to see us working with technology and producing opportunity and new trends. And, so I would ask a global question of what you gentlemen might think that your area plays into that scenario of creating the technology and then the work of the 21st century.

I am going to ask three questions and then yield back the mike so that you might answer them. I would also appreciate—and I understand that the Department is pursuing an agreement with CERN to commit the U.S. to fund part of the construction and outfitting of that large collider, and I would appreciate your comments on what you think the Department of Energy's initiative on that is.

Again, my appreciation for private and public cooperation and also my recognition that sometimes government has to initiate so that others may participate.

My other question would be with respect to how we will review your budget, and that is what has happened to the staffing levels at your laboratories in the last three years and the impact on the work of those laboratories before that.

Mr. Chairman, as I close to allow the gentlemen to answer the questions, I would ask unanimous consent to submit an opening statement for the record and to revise and extend it at a later time.

Chairman ROHRABACHER. Without objection, your full statement will be put into the record.

And, all of your questions will now—they will now have a chance to answer all of your questions.

Ms. JACKSON-LEE. That's correct. Thank you, Mr. Chairman.

Chairman ROHRABACHER. Hopefully within the five minutes that has been allotted to you for questions.

Ms. JACKSON-LEE. I appreciate the generosity and the kindness of the Chairman.

[Laughter.]

Chairman ROHRABACHER. Dr. Peoples.

Ms. JACKSON-LEE. Thank you, Mr. Chairman. Gentlemen, I hope you wrote them down.

Dr. PEOPLES. Yes.

Ms. JACKSON-LEE. All right. Thank you.

Dr. PEOPLES. I was looking for an answer for the first one, and I looked up and it says, "For I dipped into the future far as human eyes could see, saw the vision of the world and all that wonders would be."

Ms. JACKSON-LEE. Excellent.

Dr. PEOPLES. I think that's the best answer I can give. Particle physics and nuclear physics are about looking into the world that we live.

And, we don't have an immediate contribution. I will give you an example.

When Galileo got a telescope, that telescope wasn't invented to find the four moons of Jupiter that he saw. It was to see which ships came in first so that somebody could make a cleanup, because they were an hour ahead of somebody else.

The second one you asked was about the Large Hadron Collider. The Large Hadron Collider, I think, is an opportunity for scientists who work in high energy physics in the United States to continue to pursue work at the energy frontier.

In 10 years or so, that energy frontier will be in Geneva, Switzerland where the Large Hadron Collider will be. I speak now specifically as a Director of Fermi Lab. We hope that we can make a contribution to that machine, a rather modest contribution but one that will still keep our skills honed and sharp because, as Dr. Krebs said earlier, we all still have the vision that we would like to have the energy frontier come back to the United States.

The last question. We have been reducing the staff of our laboratory continuously over the last three years.

I think that you asked what happened to the size of the laboratory. And, it has gone down by roughly 300 people.

We are trying to keep our costs down in order to responsibly d science and live with the budgets that Congress and the Administration put forward.

Professor RICHTER. I think John Peoples answered the questio about applications very well. High energy physics is a progra with very long range impacts on science.

And, I don't think anybody has a clue right now as to what prac tical will come out of it. I always believed that the old saw is true Knowledge is, indeed, power. And, as we know more, we have bee able to control our world better.

The LHC program, you asked about, I, too, believe that it's goo physics. But, to do the LHC program and to maintain a health program in the United States requires some budgetary consensus

The plan that was presented to Congress in 1994 was somethin which would allow us to have a strong domestic program and t participate in this work on the frontier in Europe. Congress, i fact, when the SSC was cancelled, urged the high energy physic community for these big high ticket items to go international. W are responding.

However, the outyear budgets that were presented by the Clinton Administration with a reduction in general science from $1 billion this year to about $750 million in 2000, I think the Chairman characterized it harshly. And, I would agree with him.

It doesn't make any sense. And, if we were really going to do that, we would have to stop and reexamine the whole high energy physics program because after a cut of 25 percent over the next four or five years we could no longer participate in CERN and maintain the domestic program that we are now talking about.

You asked about staffing. Our staffing has been going down for the last three years.

We have managed in FY-1994 and 1995 to do that by attrition, by holding down hiring. We couldn't do it in 1996. In 1996, we had to go to layoffs and laid off 70 people.

Ms. JACKSON-LEE. But, is your work being done? I mean, it obviously impacts the work, I would assume.

Professor RICHTER. Our work is getting very tough to get done. We are making our users do more for themselves. That slows down the work of the users.

And, we are slowing down our program. We can't run the facilities in high energy physics as much as we would like.

The Facilities Initiative, passed by Congress for this fiscal year, has primarily benefited the synchrotron radiation program. And, their operations are good and users support is good.

The real problem at SLAC is in the high energy physics program.

Ms. JACKSON-LEE. Thank you.

Dr. SAMIOS. They gave you the poetry on the technical aspects. There are—in nuclear physics, there have been spinoffs that have been more immediate.

For instance, at our lab through the years, technicium 99, which is a bone scanning procedure, $100 million industry, that came out of the national labs; in fact, our national lab. L-dopa for Parkinson disease, is also a thing that came out of studying of radioisotopes, which is a direct benefit.

And, then there's the poetry that Burt and John told you, that you develop things that you don't know what's going to happen 10 to 20 years from now. But, I think there are immediate effects from the technical prowess of the laboratories.

The LHC is, I think, a necessity at the present time. The LHC—the SSC was roughly $8 billion to $10 billion, would have been at $8 billion to $10 billion investment. Some people say more.

And, what we are saying now is the consensus is to participate in Europe for $450 million. It seems to be a reasonable compromise.

Our laboratory is involved both in the accelerator part and as well as the detector. So, we will be active participants. And, we beieve we will be treated as full participants.

But, I think the science is valid. And, the American participation s meaningful.

I would second both Burt's and Herman's and John's comments bout the outyear projections. If they do drop, then the fields have o be reexamined.

Staffing levels, commensurate with everyone else, we have reduced from 3,500 to 3,200 over the last two to three years. We have done that mainly, as I said earlier, on our support functions.

But, unfortunately, because of the dropping of a flat scientific budget, which imply inflation, we've had to reduce staff. The place that hurts is among younger people. And, so I'm concerned that if one has tight budgets, the effect on young people.

We do have programs now for retiring people, making it lucrative to retire or, at least, not as bad as it would be. But, I think for a field to be vibrant, it really depends on young people, vibrant young people, entering the field.

And, in very fragile budget situations, that becomes at risk.

Dr. GRUNDER. I can subscribe to much of what my colleagues have said. But, let me amplify.

In addition to providing long term knowledge, knowledge which is important in the long term, we provide education of the best minds in the country. And, we set a standard of challenge for the young minds to compare.

That's not nuclear physics alone. It's other fields, too. But, it is the sciences who sets that standard.

We also are developing enabling technologies and, in particular, my lab. In pursuit of our own mission, we have developed a couple of technologies which are very likely to have near term application.

The LHC is a frontier in high energy physics. And, whether we accept it or not, the frontier will go to Europe for some time.

And, being in nuclear physics, I don't have to enter the controversy, who pays for what.

Staffing levels, CEBAF has gone down 20 percent, but careful. We also came from construction into operation and reduction of staff would have been unavoidable in one way or the other.

I am, at the moment, unable to disentangle it completely. But, I assume it's a few percent of the 20—let's call it 5—which we have gone down because of the stringent budget situation.

Thank you.

Chairman ROHRABACHER. Mr. Fawell.

Mr. FAWELL. I have nothing.

Chairman ROHRABACHER. And, Mr. Foley, from Florida.

Mr. FOLEY. No questions.

Chairman ROHRABACHER. No questions. Just a couple of thoughts from the Chairman.

I would hope that over the centuries that we've actually done more with telescopes and with magnification than just being able to see the four moons of Jupiter. I mean, I'm not quite sure whether or not if that's all we were seeing were the moons out there whether or not the investment would have necessarily been worth it.

I mean, perhaps the fact that things have to—in this world, dual benefits have to derive rather than just pure knowledge. I mean, is this—am I out of line by saying this?

Dr. PEOPLES. Seeing those moons transformed immediately the notion of what our world was like. It moved us from a world of the Aristotelian idea where it just sort of sat there to the point where there is another one of these things out there. It changed our ideas.

I think sometimes pictures—the picture taken from Apollo looking back on our world, the remarkable picture, I think that transforms people. So, sometimes knowledge transforms our understanding far beyond just the mere ability to manipulate equations.

But, we all understand that.

Chairman ROHRABACHER. At the same time, the magnification that permits us to do those things permits us also to find a cure for diseases we are talking about and—

Dr. PEOPLES. Oh, yeah. It was used for microscope, too.

Chairman ROHRABACHER. Exactly.

Dr. PEOPLES. It's very powerful. I'm sorry, I didn't pick up on that.

Chairman ROHRABACHER. That's——

Professor RICHTER. I would also like to leave the poetry to John and talk about the practical things. I think some people don't know that the enormously popular World Wide Web is a product of high energy physics.

It builds on communications work in computers that was done in high energy physics labs all around the world, reaching its culmination in a program developed at CERN to a communications between high energy physicists. I think if you just look at the economics of that, we probably paid for the whole field.

I would also note that out of the work at my own laboratory comes the technology that's used in every single medical accelerator used for cancer therapy, as well as the high power RF tubes used in radar for aircraft control. And, out of John's place comes superconducting technology that has revolutionized the way you make big magnets.

The technology that comes out of places where you've put together a lot of very smart people working on some of the hardest problems in science has enormous benefits to society. The actual benefits of the science we do today are unknowable. That's too long a horizon. But, the technology, I think, pays off and pays off well.

Chairman ROHRABACHER. Let me tell you why some people are skeptical about that, although I will not say I accept everything that you just said. When we talk about this new quark that has just been discovered—and, you know, Lord, I don't know what a quark is. And, most—90 percent of the people don't know what quarks are.

But, some of us sit back and say, "Well, does that mean all the work that was done by the physics people prior to the discovery of this quark were wrong? Does that mean it was based on false assumptions? And, if so, now is this—when is the 7th and 8th quark going to be found?"

I mean, am I being totally unreasonable?

Dr. SAMIOS. No. What is true, there are three families of quarks and only the first family is the stable family that you and I are made of—the up and down quarks that John mentioned.

There are four other ones now that are unstable. They live for short periods of time.

They are there. We don't know why they are there. The world would live maybe if they weren't there, because we are not made of them.

But, they exist. And, we don't know why they exist.

Chairman ROHRABACHER. But, the fact that you now know about them, does it negate any of the research or——

Dr. SAMIOS. No, no——

Chairman ROHRABACHER. (continuing) —any of the work that was done before we knew they were there?

Dr. SAMIOS. Because the macroscopic world is made of tables, okay. And, what happens is Newton was replaced by Einstein, okay. But, Newton was still right in the macroscopic world.

But, when you go to the subatomic world, Newton doesn't work. And, so you need relativistic equations.

So, whatever new thing comes has to encompass what was known before. But, it goes into a new regime.

Does that help you? No.

Chairman ROHRABACHER. It helps a little bit, but this is a long—this would be a long discussion over——

Professor RICHTER. Could I take a brief shot at it?

Chairman ROHRABACHER. Yes, sir.

Professor RICHTER. This is the evolution of science. Science discovers new and deeper truths all the time.

And, the new science encompasses the old.

Nick talked about Newton and Einstein. Newton's equations are absolutely right for things that move slow compared to the speed of light. In Newton's world and in the world up until quite recently, everything moved slow compared to the speed of light and it was perfectly fine.

Einstein supersedes Newton. And, Newton is a correct approximation to Einstein's equations when you are moving slow.

This is true in biology as well. You don't need to know about DNA to look at the evolution of chimpanzees and to see how they change. If you want to understand it at a deeper level, you do need to know about it.

And, so the new science encompasses and enfolds the old and transcends it.

Chairman ROHRABACHER. Well, one of the things that we decided when we took control of Congress last year—and I say we, the Republican Party, decided that we were going to try—that basic research and trying to expand basic knowledge was going to be one of our high priorities. And, I think we've tried to protect that.

And, I think that you folks represent the most basic of basic research. And, however, there is nothing more basic than you don't create something out of nothing.

And, that goes for budgeting as well. And, so if we have the money—if we spend money somewhere else, we won't have the money to spend on basic research.

And, that is probably the fundamental issue being debated in the Science Committee as compared to the fundamental issues that are being debated in the halls of science. And, I want to thank you very much for your contributions.

Mr. McHale, would you like to make a statement for the record or ask a few questions?

Mr. MCHALE. Mr. Chairman, I thank you. Just a brief observation.

I would respectfully submit that support for basic research is a scientific issue, not a partisan issue. There are very fine Members of this Committee on both sides of the aisle—Democrats and Republicans alike—who are committed to basic research.

And, I would hope that even inadvertently that the Chairman's comments would not imply that one political party or the other is more committed to that basic scientific research. Beyond that, Mr. Chairman, I thank you very much for the opportunity to make that brief and nonpartisan comment.

My hope is that after the next election, regardless of which party might be the majority that we could continue, gentlemen, to provide the kind of funding for basic research that guarantees that the fundamental discoveries of science will go forward regardless of partisan considerations.

Mr. Chairman, I just arrived in the room a moment before you last spoke because of the conflicting commitments. I simply want to extend to the panel my appreciation for their testimony.

I am reading through it right now. But, at the present time, I don't have any questions.

Thank you.

Chairman ROHRABACHER. Thank you very much, Mr. McHale. And, again, thank you to the panel.

PANEL 2—OTHER OFFICE OF ENERGY RESEARCH LABORATORY DIRECTORS

Chairman ROHRABACHER. And, we will now proceed to our second panel. Without objection, we have a Member who is not on this Subcommittee but would like to join us for the purpose of an introduction. And, Doc Hastings will join the panel.

Our second panel includes four administrators of the DOE's multi-program laboratories—Dr. David Moncton, who is Associate Laboratory Director of Argonne National Laboratory in Illinois; Dr. Alvin Trivelpiece, the Director of the Oak Ridge National Laboratory in Tennessee; Dr. Charles Shank, who directs the Lawrence Berkeley National Laboratory in California.

And, Doc Hastings, do you have an introduction that you would like to make today?

Mr. HASTINGS. Yes. Thank you, Mr. Chairman. I appreciate the opportunity and the courtesy that you give me to allow me to come over and introduce one of your witnesses today, Dr. Bill Madia from Richland.

Dr. Madia is the President of the Pacific Northwest National Lab in Richland, Washington, which is in my district. PNNL is a division of Batelle Memorial Institute.

And, Bill has been associated with that organization for a quarter of a century.

My district includes the Hanford Nuclear Reservation, which is on everybody's minds from the standpoint of cleaning up that area and leads us to the awareness of the need to do that with new technology. We have moved, in the National Security Committee, to a concept of going to performance-based contracts which is, I think, something that needs to be done to accelerate that cleanup.

In association with that then is the work that PNNL has done, because they have positioned themselves to be very much in the forefront of environmental cleanup and environmental technology.

And, Dr. Madia has led that effort, particularly in the last several years.

And, I know that he will go over that in his testimony. So, it gives me a great deal of pleasure to introduce to this Committee Dr. Bill Madia from the Pacific Northwest National Laboratory in Richland, Washington.

Chairman ROHRABACHER. Thank you, Doc Hastings. And, I would ask the panelists, if possible, if they could summarize their testimony.

Your full testimony will be put in the record. And, if you all summarize, we will have more chance for some exchange. And, we would deeply appreciate that.

Mr. FAWELL. Mr. Chairman.

Chairman ROHRABACHER. Yes.

Mr. FAWELL. If I may, I would like to also introduce——

Chairman ROHRABACHER. Oh, I'm sorry.

Mr. FAWELL. No, no, that's quite all right.

Chairman ROHRABACHER. Go right ahead.

Mr. FAWELL. I simply want to welcome Dr. Dave Moncton, who is here, from the 13th Congressional District, Argonne National Lab. He is the Associate Director at Argonne.

But, I think he is most revered or well known in the area for the tremendous job he has done as the lead person in regard to the construction of the Advanced Photon Source. And, that facility has now been constructed.

And, lo and behold, it has been constructed one year ahead of schedule and under budget. You don't have those kinds of reports that we can usually give to the Congress.

So, it's my pleasure to again welcome Dr. Moncton, who has been before this body before, in his testimony today.

Chairman ROHRABACHER. Dr. Moncton.

STATEMENT OF DR. DAVID E. MONCTON, ASSOCIATE LABORATORY DIRECTOR, ADVANCED PHOTON SOURCE, ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Dr. MONCTON. Thank you very much. I would like to begin by offering Alan Schriesheim's regrets for not being able to be here today.

Alan will be stepping down on the 1st of July after 12 years of service as Director of Argonne. And, he asked me to extend his personal thanks for the support that this Subcommittee and its predecessors have given to the laboratory over the years of his tenure as Argonne Director.

As Associate Director with responsibility for the newest of DOE's BES user facilities—that is, the $450 million Advanced Photon Source—I would also like to thank the Committee for its continued bipartisan support. Just last week, we celebrated the dedication of this facility.

I would like to apologize to Congressman Fawell, in particular, for scheduling that dedication when Congress was in session. But, we enjoyed his wife's attendance at the ceremony.

The facility has been constructed under a budget that was established back in 1987, two years before the groundbreaking. It's essentially a year ahead of schedule.

And, it has met all of its technical objectives. And, early scientific results have started to come in.

Chairman ROHRABACHER. If you would have been behind schedule, then you would have really had to schedule your opening at a time when the Congressman could be there. But, we are happy that you are on budget and under schedule.

Mr. Fawell is very proud of that, I'm sure.

Dr. MONCTON. I don't want to give you a physics lecture, but I will just say that this facility will provide the brilliant x-ray light that scientists need to see the detailed atomic makeup of the many kinds of materials which are critical to the technologies which underpin our civilization from materials from catalysts to superconductors, from designer drugs to advanced fibers for textiles. The light from this machine is so bright that a single burst lasting less than a billionth of a second can produce data which is adequate for determining the structure of very complex biological molecules.

As a result, we have now nearly 1,000 users who are planning to implement the first set of 40 beamlines.

One of the primary reasons for the success of the APS is the long-standing commitment by both the Department and Congress to adequate funding. But, the current budget climate has put severe pressure, as you've heard, on Energy Research's budget.

As a consequence, the FY-1997 budget for the APS is $4.1 million below the FY-1996 budget. In order to fund increased utility expenses associated with beginning operations, full operations, and to hire staff for overseeing the user program, we had been seeking for many years a budget for FY-1997 that was $9.8 million higher than what we had in 1996. So, this is almost a $14 million shortfall.

But, with substantially increased risk due to the lack of spare components and with the use of forward financing, funds that have been accumulated over the first six or seven years of the project, we are trying as hard as we can to plan a full operating program for 1997. It won't be easy.

I just caution this Committee that any significant further reductions by Congress or by the Department could lead to reductions in experimental beam time. And, the research of this enormous group of scientists from over 140 universities, federal laboratories and industries is really at significant risk.

And, flat budgets for the foreseeable future will require reduced operations in subsequent years after we deplete our—after we effectively eat our seed corn here in the next year. These budget problems, which we are experiencing, have been common among DOE facilities in the last decade.

Small budget cuts have accumulated to cause highly inefficient use of facilities in most of the labs represented here today. To address this issue, the DOE developed the Scientific Facilities Initiative in FY-1996.

The concept was an excellent one. And, you've heard from the previous panel, and you will hear from this panel, the impacts that it has had in the facilities in all of our laboratories.

But, I want to call your attention to two concerns. First, that the constrained budgets for the Office of Energy Research for FY-1997 have already begun to erode the gains made by the Initiative in

FY-1996; and, second, that for us at Argonne the APS faces a very serious problem for full operations that is similar to the other facilities before the Initiative was implemented.

The Department has recently indicated that it will conduct a review of our projected operating costs in order to make sure appropriate levels are established. And, we are very encouraged by this development. We look forward to the review.

Let me just conclude with one comment. I'm afraid that in our zeal to cut budgets we have sometimes forgotten where our technologies originate.

Our government apparently cannot afford increases for basic research if we take at face value the projections for the outyears. But, my believe is that in reality the country cannot afford the damage to our basic research enterprise that is implied by flat or decreasing outyear budgets for the Department of Energy.

So, I strongly encourage this Committee to support the current budget levels as an absolute minimum level and to work with the Administration to restore the outyear budgets to healthy levels.

Thank you very much.

[The prepared statement of Dr. Moncton follows:]

Testimony Before the

Subcommittee on Energy and Environment of the Committee on Science U.S. House of Representatives

David E. Moncton
Associate Laboratory Director
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May 8, 1996

Mr. Chairman and Members of the Subcommittee:

I would like to thank the subcommittee for the opportunity to testify on behalf of the Department of Energy's scientific facilities, in particular, and on the overall budget for the Office of Energy Research (OER). Let me first offer Alan Schriesheim's regrets -- a previous commitment could not be broken. As Alan is preparing to step down from twelve years of service as director of Argonne National Laboratory, he wanted me to extend his personal thanks for the support this committee and its predecessors have given to the laboratory and its programs over these years.

As one of the nation's first national laboratories, Argonne is this year celebrating its 50th anniversary. The Laboratory's initial mission was nuclear energy technology and supporting science for power generation. Today, funding from the Office of Nuclear Energy, Science and Technology still supports 24 percent of the Laboratory's work for DOE. The Office of Energy Research is now our largest sponsor, accounting for 45 percent. Construction and operation of scientific user facilities is a major part of this work for OER. Argonne's total funding in FY 1996 is $485 million.

As Associate Laboratory Director with responsibility for the newest of DOE's BES user facilities -- the Argonne Advanced Photon Source (APS) -- I would also like to thank this committee for its continued bipartisan support. Just last week we celebrated the dedication of this facility, which has been constructed under the 1987 budget estimate and a year ahead of schedule. It has met all of its technical operating goals, and early scientific results have started coming in. Hundreds of users in the next few months will grow to thousands over the next few years, as this machine returns real scientific value for the taxpayers investment. As many of the members know, this facility will provide the brilliant x-ray light scientists need to see the detailed atomic makeup of the materials which are critical to technologies from catalysts to superconductors, from designer drugs to advanced fibers for textiles. The light is so bright that a single burst lasting less than a billionth of a second is enough to see the structure of a complex biological molecule. Motion pictures of molecules at work will provide the insight scientists need to understand and exploit, for example, how nature designs biological structures.

One of the primary reasons for the success of the APS is the long-standing commitment by both DOE and Congress to adequate funding. The current budget climate has put severe pressure on OER's budget. As a consequence the FY97 President's Budget is $4.1M less than the FY96 President's Budget. In order to fund the increased utility expenses associated with full operations, and to provide support to users on the experimental floor, we had long requested a budget $9.8M higher than FY96. With the substantially increased risk of downtime due to lack of spare components, and with the use of previously accumulated forward financing, we are making every effort to plan a full operating program for FY97. But any significant further reductions by Congress or by the DOE could lead to reductions in experimental beamtime. Over 500 scientists from 140 universities, federal laboratories, and industries are at significant risk. And flat budgets for the foreseeable future will require reducing operations after the depletion of our current reserves.

The budget problems just now being experienced by APS have been common among the DOE facilities in the last decade, as small budget cuts accumulated to cause highly inefficient use of facilities in most of the labs represented here today. To address this issue, the DOE developed the Scientific Facilities Initiative (SFI) in FY96. The concept was an excellent one and I have included comments below which describe improvements that these funds have achieved at Argonne. Now, I wish to call the subcommittee's attention to two concerns: first, that the very constrained budget that the Office of Energy Research is now facing has already begun to erode the gains made by the Initiative; and second, that the APS (which was not officially part of the Initiative) faces a very serious problem for full operations similar to that experienced by other facilities before the Initiative was implemented. I strongly support the Scientific Facilities Initiative, and hope that in its spirit, funds might be made available to provide a fully effective program for the APS as it becomes an operational facility. The Department has recently indicated that it will conduct a review of our projected operating costs in order to make sure appropriate levels are established. We are very encouraged by this development and look forward to the review.

A closely related area involves DOE's Biological and Environmental Research program. This effort has three main objectives: to contribute to a healthy citizenry, to contribute to cleaning up the environment, and to understand global environmental change. At Argonne, the program supports the premier Structural Biology Center based on the Advanced Photon Source, development of human genome sequencing technology, operation of the world-class Cloud and Radiation Testbed climate measurement site, and health effects research. Efficient utilization of investments made in the Structural Biology Center will require the $3.3M in FY97 operating funds that had been previously planned. Also, funding for health effects research, which has been decimated over the years, should be restored to support important research into cellular and molecular effects of energy by-products.

One of the biggest challenges facing us in the future will be providing efficient network access to unique facilities within the DOE system. DOE 2000 is an initiative that will enable DOE scientists and engineers at a number of DOE and other facilities to collaborate on solving problems using advanced networking techniques and virtual reality computing. The initiative will also develop computer simulation techniques to be used in place of experiments where real experiments are too dangerous, expensive, inaccessible, or politically infeasible. For this initiative to go forward, it is important that the President's budget request for Mathematical, Information, and Computation Sciences within the Computational and Technology Research Program be strongly supported in Congress.

I recently returned from a visit to our sister facility, SPring-8 in Japan, to observe their progress and to discuss how we might increase our collaborations in order to stretch our scarce funds. In the field of synchrotron radiation, the Japanese have made the equivalent of 20 years of progress in the last decade. With the commissioning of their new facility in early 1997, they will have produced the world's most powerful source with 25% larger capacity than the APS -- in a country with half our population! They plan to operate it with a budget almost double ours, so that they can more rapidly implement its full potential. In addition, in the field of neutron facilities, they completely refurbished the Tokai (JRR 3M, 20MW) reactor in 1992, and I learned that they are now committed to a new 600kW spallation neutron source at the KEK laboratory.

I asked my Japanese hosts why they were making such a substantial investment in new scientific facilities during a time of economic difficulty in Japan. They explained that the current philosophy is based on a deep appreciation of the benefit that has accrued to Japan from post-war investments in basic research in the West. Recognizing that the U.S. and Europe are currently underinvesting in basic research, they feel it is now their duty to compensate, so that the world can continue to reap the benefits of science. My reaction, and perhaps yours, might be a mixture of gratitude tempered by unease. One might wonder whether their motives are so charitable. Given what they were able to do when they faced the barriers inherent in assimilating foreign research results and turning them into applications, I suspect they enthusiastically await the day when the tables are turned and we must attempt to use Japanese basic research results to drive our industries.

In conclusion, let me say that I am afraid that in our zeal to cut budgets, we sometimes have forgotten where our technologies originated. Our government apparently cannot afford increases for basic research, but in reality the country cannot afford the damage to our basic research enterprise that is implied by flat future DOE budgets. I strongly encourage this committee to support the current budget levels as a minimum, and to work with the administration to restore the outyear budgets to healthy levels.

Impact of the Scientific Facilities Initiative at Argonne

The **Intense Pulsed Neutron Source (IPNS)** has operated as a user facility for neutron scattering since it turned on in 1981. Decreases in the DOE operating budget have reduced IPNS operation to 16 weeks per year. In addition, lack of scientific support has resulted in most instruments operating less than the planned 75% for the user program. The goal under the SFI is to double operation and provide scientific support for the neutron scattering instruments to permit all instruments to be run in the full user mode. The increase from 16 to 32 weeks of annual operation is planned to take place over 2 years as personnel are hired, with 25 weeks scheduled for FY 1996. Due to the complexity of the instruments and data analysis, personnel are vital to provide the necessary support for the additional outside users doing experiments at IPNS as part of the SFI. Ten new post docs will be hired to support the increased user program and the following staff positions have been filled: two accelerator physicists, a design engineer for instruments and target stations, engineer for cryogenic moderators, scientific assistant for the powder diffractometer, and scientific assistant for the neutron scattering ancillary equipment. At the Program Advisory Committee (PAC) meeting in Dec. 1995, the number of instrument days allocated by the PAC for the cycle starting in late Jan. 1996 was increased from 200 to 317 days, an increase of more than 50%.

Argonne Tandem-Linac Accelerator System (ATLAS). Beams from ATLAS continue to be in heavy demand from a wide variety of users. Several low energy nuclear physics laboratories around the world have been closed down in recent years, while ATLAS was upgraded with the addition of the Positive-ion Injector. There are now over 150 active users of ATLAS from 46 different institutions pursuing a wide variety of basic research programs. With incremental funding from the DOE Scientific Facilities Initiative, ATLAS is now operating routinely 24 hours per day and seven days per week. The incremental funding of $600K was 12% of the ATLAS operating budget, but this enables 60% more beam hours on target per year than was possible in the past with 5-day per week schedules. The additional staff and supplies supported by the Scientific Facilities Initiative make possible the more efficient operations associated with continuous operation of the accelerator and cryogenics systems as well as freeing up some of the more specialized support staff for ongoing maintenance and upgrade projects. Efficient integration of new equipment such as the second, advanced ECR ion source currently under construction would be delayed considerably in the absence of the incremental funding provided by this initiative. Even at the present increased funding level, however, most of the ATLAS operations staff is involved in providing backup support for the off-shift and weekend running. Cellular phones and pagers have become part of the way of life at ATLAS.

HVEM-Tandem User Facility. This DOE user facility, whose primary research is the use of electron microscopy for fundamental studies of particle irradiation effects in metals, glasses, semiconductors and superconductors, has employed the money from the SFI to increase equipment performance and reliability, and to add staff to increase operations from 40 to 60 hours per week (50 weeks per year). Further increases in operating time will be possible over the next two years, allowing for more experimental time to users whom we are currently turning away or limiting their experimental time. Increased experimental time will also permit us to schedule some experiments which are more creative and thus risky, for example the possible formation of unique structures and properties in semiconductors and superconductors by controlled electron and ion irradiations.

Chairman ROHRABACHER. Well, we certainly will not have the money for the basic research that you are talking about. As you say, it's one of the building blocks that sometimes are forgotten about, the foundation.

Sometimes you are so busy trying to build the machines that are going to produce the product that you forget you have to have a foundation for the building to—for those machines to stand upon. But, if we are going to be spending money on marketing programs, we are going to be spending money on promoting specific types of technology overseas for sales, if we are going to become—if we are going to get in partnerships with business and pay their licensing fees, well, then basic research is going to be hurt because we only have a certain limited amount of money.

And, that's what the central debate is in this town today.

Dr. Trivelpiece.

STATEMENT OF DR. ALVIN W. TRIVELPIECE, DIRECTOR, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE

Dr. TRIVELPIECE. Thank you, Mr. Chairman. I've had the privilege of appearing before this Committee many times.

And, it struck me in listening to my colleagues testify earlier that there was a period in my life in which I think I was the youngest whatever it was that I was doing. Time has passed. I now seem to be the oldest whatever it is that I'm doing.

But, that being the oldest also gives me a certain span of memory. And, one of the aspects that memory has to do with is the creation of the Department of Energy.

And, in its creation, if you look at the legislative record of the hearings that led up to that, the Office of Energy Research was created with a Director and not with an Assistant Secretary. There are eight Assistant Secretaries and a Director of Energy Research.

That office was endowed with certain responsibilities which, in a sense, makes the Director of the Science a Secretary, among other things. But, it was also created, in that sense, with the intention that it be the fourth ranking element of the Department of Energy.

The Director of Energy Research was supposed to be fourth in succession in the Department. Now, one of my predecessors, since I had that job, was Dr. Deutch. Dr. Deutch was more dynamic than I was and I think he probably caused that to occur.

But, subsequent to that, that really hasn't been essentially observed within the Department. But, that's not the point that I wanted to make.

The point was that in a Cabinet department with all the various political puts and takes and pushes and pulls that occur, the intent was to provide the Office of Energy Research as the basic science element of the Department a certain degree of shielding from that buffeting. That is more difficult to do today because, in a sense, basic research, as it is in private industry, is a variable overhead expense.

And, when you look at the operation of government, presidents of the United States as well as presidents of companies have to look at the elements of their budgets or the variable overhead expenses. And, many companies have eliminated their research enterprises within them and, I think, to their detriment.

And, I hope that the nation doesn't do the same in looking at its variable overhead expenses simply because that's the place where you can get the easiest cut with the least complaint to go after the research programs. And, I agree with Dr. Krebs, the Office of Energy Research, created by the Administration and by the Congress, should be given an equal status and standing with that of the National Institutes of Health and the National Science Foundation in terms of its role and value as an element of the nation's science enterprise.

Thank you.

[The prepared statement of Dr. Trivelpiece follows:]

Proposed Testimony of

Alvin W. Trivelpiece
Director
OAK RIDGE NATIONAL LABORATORY

on

The Department of Energy's
Office of Energy Research Programs
and
Scientific Facilities Initiative

before the

COMMITTEE ON SCIENCE
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
U.S. HOUSE OF REPRESENTATIVES

May 8, 1996

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
Managed by
Lockheed Martin Energy Research Corporation
for the
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Mr. Chairmen and Members of the Subcommittees, I am pleased to have the opportunity to testify before this Committee to present my views on the Department of Energy (DOE) research programs in the Office of Energy Research and the Scientific Facilities Initiative.

The mission of the Oak Ridge National Laboratory (ORNL) is to conduct basic and applied research and development in order to advance the nation's energy resources, environmental quality, and scientific knowledge and to contribute to educational foundations and national economic competitiveness. The Laboratory collaborates with other federal agencies, industry, and universities. It is committed to excellence in all its activities and will be operated in full compliance with environmental, safety, and health laws and regulations.

Elements of ORNL's research for the Office of Energy Research include neutron sciences, fusion research, computational science, material sciences, health sciences and biology, and environmental sciences. In its role as an energy multiprogram national laboratory, ORNL combines the talents of its own staff with those of over 4000 guest scientists and engineers from academia and industry in conducting a variety of research and development activities. In my testimony today, I am going to briefly describe some of ORNL's activities supported through the Office of Energy Research. Several threads connect these activities: these are solutions to problems involving the large facilities and unique capabilities found only at ORNL, and the science focuses on problems that individual industrial companies have not chosen to fund.

Scientific Facilities Initiative

The DOE Scientific Facilities Initiative (SFI) is a sound program that is of great value. The money appropriated by Congress in the 1996 budget went directly to improve access to major DOE user facilities by scientists and engineers from universities, industry, and other government laboratories. The facilities represent a major investment by the federal government, they are utilized each year by over 15,000 users who come to the DOE Laboratories to perform scientific investigations that could not be done anywhere else. The facilities range all the way from complex facilities such as neutron sources and synchrotron light sources to much simpler facilities such as atomic resolution electron microscopes. In all instances, however, they make possible research that investigators would not likely be able to do at their home institutions.

The $100 million from the SFI that was distributed among the many DOE user facilities represented an increase in operating funds of only about 10 percent, but the impact on increased availability and future capabilities is many times that. At the High Flux Isotope Reactor (HFIR) at ORNL, for example, the SFI funds provided improved instrumentation and staff support for users that will increase availability of existing capabilities by over 30 percent. More significantly, however, it has allowed us to start the development of a new cold neutron source capability that will fundamentally change and improve HFIR for the future. Cold neutron studies are one of the fastest growing areas of research in neutron science with a rapidly increasing user demand. And even though HFIR has the highest thermal neutron flux of any reactor in the world, it has never had a cold neutron source because it was constructed in 1965 before the cold source technology was available. Some of our SFI funds will be used for a cold source retrofitted into an existing beam tube at HFIR that will produce cold neutron beams with intensities as good as or better than the best in the world. In the limited space here it is not possible to go into detail about what cold neutrons are and why they are important. In general, the "colder" a neutron is, the slower it is moving. The slower it moves, the more details it can reveal regarding the structure of matter. In the upgraded facility, the neutrons will be cooled to the point where they are moving at about the speed of someone walking. This slow speed is accomplished by allowing the neutrons to pass through a chamber filled with liquid hydrogen.

I have strongly supported the SFI from its inception. It is an excellent example of prudent expenditures that leverage existing investments and allow all the DOE user facilities to be more responsive to the nation's scientific needs. I believe that it should be continued. I know that this brings up the question, at the expense of what? I am concerned that the drive for fiscal conservatism, which I support, is being misapplied when applied to some activities that return enormous, but difficult to quantify value. If the United States is to remain competitive in areas of science and technology vital to its interest, the investment begins here. Without the tools, discoveries cannot be made. Without discoveries, there will be fewer applications of value. Without applications, certain areas of our knowledge base wither and atrophy from underutilization.

Neutron Science

The Importance of Neutron Science. In the late 1940s, Clifford Shull and Ernie Wollan began experiments using neutron beams from the Graphite Reactor at ORNL and a diffractometer borrowed from Arthur Compton's Metallurgy Lab at the University of Chicago. These experiments would eventually result in Shull sharing the 1994 Nobel Prize in Physics with Bertram Brockhouse for their collective contribution to the field of neutron scattering. This pioneering event has had at least two notable and lasting consequences. First, it set the trend for using major facilities designed, constructed, and operated by what are now the DOE National Laboratories for the benefit of all of science and industry. This unique DOE mission remains vital to this day and has added a dimension to U.S. science and technology that has been copied all over the world. Second, it essentially started what is now the field of neutron scattering. From the time Shull performed his pioneering work until he received the 1994 Nobel Prize, no less that eight other Nobel Prizes were awarded for work that grew out of and benefited directly from neutron science.

The DOE has striven to continue its leadership in developing major facilities that have kept U.S. science in many areas in a premier position. The Office of Energy Research has been the principal agent of this effort. It has succeeded well, but has not been given all the recognition it deserves as a major element in the United States' science and technology enterprise. I believe that the Office of Energy Research should be considered on an equal footing basis with the National Institutes of Health and the National Science Foundation as a first priority in the assignment of funds for federally supported research and development.

In spite of well-intentioned efforts to keep it funded at an appropriate level, the U.S. is dangerously behind other nations in the area of neutron science. Although the DOE largely pioneered neutron science with the construction of research reactors and accelerator-based spallation sources throughout the 1960s and early 1970s, Europe and Japan utilized our early developments at these facilities to construct new and better neutron sources and instrumentation that have given them the leading sources in the world for the last 20 years. Materials science and engineering, new materials development, polymer science, chemistry, biology, nondestructive testing, and many industrial, medical, and military applications benefit directly and often uniquely from neutron science. These fields drive much of the world's economy, and without a competitive neutron science capability in the near future, the U.S. will fall still further behind the rest of the world in this critical area of basic and applied science.

Justification and Need for New Neutron Sources. Numerous National Research Council studies and DOE assessments since the 1970s have firmly established the need and justification for new neutron sources. In the 1996 budget, DOE has proposed and Congress has appropriated funds to initiate R&D and conceptual design studies on a new accelerator-based, spallation neutron source that, if completed, would become the most powerful and useful source in the world for neutron scattering. The ORNL was given responsibility for the conceptual design and has initiated a collaborative effort with the Brookhaven National Laboratory, the Lawrence Berkeley National Laboratory, and the Los Alamos National Laboratory that consolidates the best available expertise in accelerators, targets, instrumentation, and experimental systems. Other laboratories, universities, and industry will be included as this new source progresses. The collaborative project is on schedule to complete the conceptual design in time to request line item status in the FY 1998 budget.

As a follow-on to previous assessments by the scientific community, and at the request of Congress, the DOE asked the Basic Energy Sciences Advisory Committee (BESAC) to reassess the needs of the neutron science community. In response, the BESAC formed three panels in 1996 to make recommendations on the scope and trade-offs for the next-generation spallation source, and to evaluate upgrades of existing reactor and spallation sources as a cost-effective means of providing neutrons to the scientific community while the next-generation source is developed. ORNL strongly endorses the recommendations of the BESAC, which reflect a responsible and cost-effective approach to solving the short- and long-term problems of the neutron community. These recommendations were:

1. Next-Generation Spallation Neutron Source: Russell Panel
   "There is an urgent need to build a short pulsed spallation source in the 1-MW power range dedicated to neutron scattering with sufficient design flexibility such that it can be operated at a significantly higher power in a later stage."
2. Upgrades of Existing Research Reactors: Birgeneau Panel
   "The panel recommends strongly that the Department of Energy proceed with both the HFBR and HFIR upgrades. These are extraordinarily cost-effective proposals which will guarantee U.S. prominence in neutron research well into the next century." (The HFBR and HFIR research reactors are at Brookhaven and Oak Ridge National Laboratories, respectively).
3. Upgrades of Existing Spallation Sources: Aeppli Panel
   "The Aeppli subpanel report makes a compelling case for the need in the neutron scattering community for a short pulse neutron source capability in the ISIS class

within the next two to four years." (The ISIS is a spallation neutron source in England.)

"Based upon this cost, BESAC does not recommend proceeding with the IPNS upgrade. It is our view that an interim project of this magnitude is not justified." (The cost estimate for the proposed Intense Pulsed Neutron Source [IPNS] upgrade at Argonne National Laboratory was $450 million.)

"It is the recommendation of BESAC that DP and ER jointly develop a plan to exploit the long pulse spallation source." (DP and ER refer to DOE Defense Programs and Energy Research, respectively, and the proposed long pulse upgrade is to the Los Alamos National Laboratory's LANSCE facility.)

The Future of Neutron Science. Neutron science is at a crossroads in U.S. science policy. The European and Japanese communities have continually upgraded and built new sources and have neutron user communities more than double the size of those in the U.S. The Japanese have just committed funds to construct a new 0.6-MW spallation source that is upgradable to 1.2 MW. The European Spallation Source project is completing a feasibility study for a 5-MW facility. Unless the U.S. proceeds with plans to construct a 1.0-MW facility that is upgradable to 5.0 MW, our nation will have nothing comparable. Similarly, our research reactors are seriously dated. The ILL reactor in France was just recently completely refurbished, and Germany is beginning construction on a new reactor. It is important to stress that these expansions are to achieve high source intensities and to serve the burgeoning user community worldwide. Unless the U.S. proceeds with the new spallation source and reactor upgrades, we will fall behind in one area in which we have long maintained prominence - that of neutron scattering, and those scientists will be forced to do experiments abroad to remain competitive.

Fusion Energy

The Fusion Energy Program at ORNL is part of the national effort recently evaluated by the Fusion Energy Advisory Committee (FEAC). This Committee has recommended the refocussing of the fusion program to place more emphasis on basic plasma science and technology than on the ultimate energy application. This is sound advice given the budget realities and the long-term schedule for fusion energy development. Collaboration within the United States and with other nations continues to be important to the success of the fusion program. International collaboration is essential to realizing the potential of fusion as an energy source. The world program on fusion energy development is now much stronger than the U.S. program. ORNL plays a major role in supporting joint programs through its strong programs in plasma science and technology — confinement concept development, fueling, heating, particle control, diagnostics, theory, computing, and materials development. Two of ORNL's many contributions are used worldwide. The spherical torus concept developed at ORNL is receiving a lot of attention throughout the world. Experiments of this type have been built or are proposed in the U.S., England, Japan, and Russia. ORNL-developed fueling and heating systems are used in many fusion laboratories in the U.S. and abroad.

The International Thermonuclear Experimental Reactor (ITER) Engineering Design Activity is a logical vehicle for the focus of the energy component of the U.S. fusion program. The U.S. has played a major role in developing this program. ITER drives the consistent and timely development of key scientific and technological elements of plasma science and fusion energy. If ITER construction is undertaken, it will be funded primarily by our international partners. Continued collaboration on ITER is a cost-effective way for the U.S. to remain abreast of fusion energy developments, while contributing mainly to underlying plasma science and technology. Within the fusion program, the development of plasma science and its related technologies has produced spin-offs which have become of vital importance to some of the world's largest industries, especially the electronics industry, where plasma processes are essential to manufacturing today's and tomorrow's integrated circuits for computers.

Computing
Access to high-performance computing capabilities remains essential for all DOE's scientists. Without such access, it is not possible to make progress in certain areas of basic and applied research and national security. The scientists and engineers at the DOE national laboratories now have the capability of addressing problems that were previously inaccessible to direct simulation. This has occurred across a broad front, from fundamental studies of melting, to classical simulations of complex materials phenomena in polymers, engineered and novel structures, and metals, to fully quantum mechanical treatments of mesoscale phenomena involving the interactions between 100's to 1000's of atoms. This will be enhanced by the DOE 2000 program which is committed to a distributed computing environment, that is, linking computer resources at other research institutions through high-speed computer networks. Goals include remotely performing experiments at major research facilities via the Internet. For example, a researcher could use Oak Ridge's HFIR without leaving the office at Lawrence Berkeley National Laboratory or a researcher in Oak Ridge could use the Advanced Light Source at Lawrence Berkeley National Laboratory. Oak Ridge has developed an on-line neutron scattering spectrometer at the HFIR as well as an on-line electron microscope at ORNL's High Temperature Materials Laboratory to permit characterization of materials while being anywhere on the Internet. While developing these collaboratories is one goal, another is to build the infrastructure to allow the face-to-face communication, common white boards, and other tools that allow researchers to interact as they do when they are physically in the same place.

In an exploratory effort, Sandia and Oak Ridge are partnering to develop high-performance computing technologies for the 21st century. Scaleable algorithms, software tools and applications software will be developed for mission-critical DOE problems in energy research, national security and environmental remediation. Important goals include establishing a 10 TeraFlops computational capability and creating a distributed computing environment for access by all of the national laboratories, including highly effective storage and access of large, distributed files. This proposal will extend DOE's pioneering leadership in high-performance computing and create a computational predictive capability for the laboratories, for DOE, and for the nation. This technology will be critical in the future as we increasingly replace large-scale tests, trial-and-error experiments and extensive prototyping with computer simulations. Other partners in this future effort include the University of California at Santa Barbara, a National Science Foundation supercomputing center, and several Department of Defense laboratories. Given the critical role of materials science in the partnership, it should be noted that these are among the world's leaders in materials research.

Sandia and Oak Ridge are among the leaders in the development and application of high-performance computing technologies. The laboratories have won national awards, set world records and developed broadly-used software. Oak Ridge and Sandia are currently in the midst of a ground-breaking experiment to run applications in the areas of global climate modeling, materials science, and impact physics on a virtual computer distributed between the two laboratories. This virtual computer consists of the world's largest Intel Paragons connected by a dedicated high-speed link. This experiment proves the viability of a collaboratory and will produce scientific results that cannot be obtained from any single computer available today. As noted for Oak Ridge, Sandia is also placing computational capabilities and experimental facilities on-line so that the laboratories can more easily share resources.

The proposed collaboration presents many exciting opportunities in systems and software tools development. One of the top issues is creating a software infrastructure for a distributed, multi-teraflop facility that could be used as the centerpiece for DOE 2000. The system software and tools must present an easy-to-use environment to the scientist while providing performance from supercomputers distributed across the country.

Education

Some of the first reports prepared by the advisory committee to the Manhattan Engineering District after World War II, stress that education should be one of the missions of the newly-formed national laboratories. This was not to be a role that replaced that of the traditional academic institutions, but rather one that disseminated the new knowledge being generated to the broadest possible collection of our citizens. The importance of that role has not diminished since it was first identified in 1947, The United States has a significant stake in ensuring that the American public is scientifically and technically literate. This includes having an adequate number of well-prepared mathematicians, scientists, engineers, and technicians. The DOE and the science-rich resources of its national laboratories and research facilities have played a key role, through their science education programs and in partnership with other federal agencies, businesses, industries, and community groups, in addressing: the need to maintain our leadership in science, engineering, and technology; the ability of the U.S. to compete in a global economy; and poor student performance in mathematics and science in contrast to other industrialized nations.

The DOE's science education program in 1995 reached more than 1 million students, educators, and members of the public. Some programs were national in scope; some were regional or local. These programs supplemented and enhanced programs offered by academic institutions and used the DOE resources to provide research and educational experiences not otherwise available to students, faculty, and the public.

Throughout its 50-year history, ORNL's major R&D thrusts in energy, environment, and basic and applied science have been closely coupled to support for mathematics, science, and engineering education. ORNL continues to offer an array of research-participation, education, and training opportunities for students, teachers, and faculty members at all academic levels, from the early elementary years through graduate and postgraduate study and advanced training and professional development.

Let me give you a snapshot of the variety of education programs at ORNL. At the recent ORNL Awards Night, where outstanding contributions in research are recognized, 18 of the 66 awards went to post-doctoral students or their mentors. The research of post-docs can involve imaging individual atoms, looking at DNA as a "fingerprint," studying the effect of drought on various trees in a forest, and new battery technology. Clearly, post-docs make an immediate contribution to the scientific community and to the economic competitiveness of the nation.

The Oak Ridge Educational Network (OREN) links schools and individuals to the greater Internet system for global communications, networking, and access to specialized information sources, DOE's National Education Supercomputer, and other telecommunications networks. OREN builds on the resources ORNL to ensure that students and educators are prepared for the communication tools and information retrieval techniques of the future. Student/faculty research participation provides research opportunities for hundreds of undergraduate and graduate students and faculty as well as high school teachers. Educational partnerships with more than 60 elementary and secondary schools and/or school systems, colleges, and universities emphasize outreach to underrepresented and underserved populations, including women, minorities, the economically disadvantaged, and people with disabilities.

You may have noticed that I used 1995 figures when talking about DOE's involvement in education. Funding for many of the education programs supported by DOE was severely cut in FY 1996 and these programs were significantly impacted. DOE education programs are again in serious trouble in the 1997 budget. It seems clear that DOE has a valuable role to play in science and technology education as it links its unique scientific resources to the education enterprise. The recent change in placing responsibility for management of the DOE's education activity back under the Office of Energy Research strengthens the relationship between the research and education missions of DOE. Both research and education benefit as they partner in the related activities. It is important not only that the DOE laboratories remain strong but also that funding is available to support those educational initiatives which link the resources of the laboratory to the broader community. While size and structure of the Department's programs that involve education should always be reviewed and justified on an ongoing basis, I would hope that careful consideration is given to them, and that they are not eliminated, because they do play a unique role in our nation's educational enterprise.

Integration of Basic and Applied Research

Collaborations among scientists and engineers from many disciplines, and from many institutions, including academia, industry, and national laboratories, are a strong tradition in the materials R&D community. The national laboratories serve several integrating functions for the DOE basic and applied programs. At the multiprogram laboratories in particular, the proximity of basic research and applied work creates advantages for both areas. The national laboratories carry out joint research with universities and interact with industry. Materials is a field with tremendous integration. The tradition of integrated materials R&D is found at all of the national laboratories and involves all major programs in DOE. The user facilities represent one area in which this integration is easily visible. The Basic Energy Sciences program of the Office of Energy Research sponsors a microcharacterization user facility at ORNL as part of the Shared Research Equipment Program. This makes analytical electron microscopes and mechanical microprobes available to academia, industry, and other national laboratories. Within ORNL, nearly half of those using materials facilities are funded by programs other than the Office of Basic Energy Sciences, and there is no charge to these programs for that use. Historically, nearly one-third of the cost for instrumentation on materials user facilities were funded by other DOE programs. When programs work together on user facilities, new capabilities can be gained that could not be developed individually, and benefits are gained throughout DOE programs and to the external users

ORNL's nickel and iron aluminides are recognized and valued for their high strength performance at high temperatures. Research on these materials has required the participation of several DOE programs and from industry. Energy Efficiency was interested in development of an alloy for high-temperature strength and oxidation and corrosion resistance. Basic Energy Sciences was interested in determining why the introduction of small amounts of boron improved manufacturability and produced alloys that resist deformation and fracture. Fossil Energy was focusing on development of an alloy for use in a high-sulfur environment. The work sponsored by these organizations developed to a point where industrial input was received to identify applications and permit applications testing. Cooperative Research and Development Agreements for specific applications followed detailed data base development of alloy characteristics and scale-up. To date there are fourteen licenses for these intermetallics. From their initial development, a wide range of industrial products and a new subfield of alloys science have evolved. A new scientific journal, Intermetallics, was started in 1992 through the efforts of many ORNL scientists. The products include furnace rollers developed by Metallamics, magnet dies developed by Magnequence, and furnace trays for General Motors. Research on intermetallic materials involves the participation of several DOE programs. Although this description implies a linear approach to research and development, it is actually an iterative process in which basic and applied programs are true partners. Each advances with the achievements of the other.

Ceramics R&D has also benefited from integrated R&D carried out by teams from different areas. Basic Energy Sciences research on toughening ceramics fostered the development of silicon carbide reinforced alumina under Energy Efficiency. The resulting products have attracted new industries to Oak Ridge, and there are now over $30 million in annual sales of ceramic cutting tools and related products. Two DOE programs (Basic Energy Sciences program in the Office of Energy Research and the Energy Efficiency program), the National Institute of Standards and Technology (NIST), Advanced Research Projects Agency, and AlliedSignal Ceramic Components contributed to the development of gelcasting. Gelcasting is a process in which ceramics are cast in a form very close to the final shape to minimize costly and time-consuming machining of the tough ceramic material. The initial discovery was made in ORNL's Energy Efficiency program. Researchers used Basic Energy Sciences powder processing expertise to further commercialization efforts to understand slurry behavior and further development efforts. The NIST Advanced Technology Program funded commercialization efforts between ORNL and AlliedSignal. Not yet complete, this product may permit American industry to develop a process that will reduce machining costs and make them more price competitive.

Successful integration of R&D occurs among DOE programs using many paths. Perhaps the best motivator occurs when research needs are coincident. This is driven primarily by the principal investigator and can be aided through joint planning activities like workshops. Having basic and applied programs at the same institution helps by leveraging expertise through the cofunding of individuals or their teams. One key to this is flexibility in research direction. As in any partnering activity, no single DOE program needs to force the direction of the overall effort; the enthusiastic support of all DOE program offices is integral to this success. All participants, and their sponsors, must be willing to share success. Industry is a natural beneficiary and partner in many successful integrated R&D programs, although the degree and time to achieve integration does not follow a single formula.

High-Temperature Superconductivity

In 1986, scientists at an IBM research laboratory in Switzerland discovered that certain materials would conduct electricity with essentially no resistance at temperatures far higher than those previously known. Since then, research has focused on identifying materials that would be superconducting at these high temperatures, and could be cost-effectively manufactured. Recently, ORNL demonstrated the feasibility of a new method to fabricate very high current conductors based on the high-temperature superconducting (HTS) material yttrium-barium-copper oxide. When applied on a large scale, this new method will result in conductors which will function without electrical resistance in high magnetic fields near the boiling point of liquid nitrogen. The novel approach uses metal strips which, through special fabrication processes invented and developed at ORNL, have a high degree of crystallographic alignment, or "texture." When a thin layer of the superconductor is correctly deposited on the strip, the texture of the strip is imparted to the superconductor. It has been known for several years that such texture is required for the superconductor to carry high currents. The critical current density obtained, 600,000 amperes per square centimeter at 77K, is the highest obtained by any process considered scaleable to production of long lengths of wire. In contrast, conventional wires in our home operate in the region of 1000 amperes per square centimeter.

This interdisciplinary project has been supported jointly by programs under two DOE Assistant Secretaries: Energy Efficiency and Renewable Energy's Superconductivity Systems Program and the Office of Energy Research's Basic Energy Sciences program. Success of this project, which has been conducted over several years by a team which in the last two years has involved as many as 15 researchers, is a clear demonstration of the value of the broad expertise residing at ORNL and of the ability of ORNL's staff to focus its efforts on a long-range applied project. Because of the long-range, speculative nature of this project in its early stages, there were no efforts in private U.S. industry with similar goals.

This new conductor technology developed at ORNL enables further research and development on HTS wires and cables for use in power transmission lines, transformers, fault current limiters, motors, and generators, which will operate at or near liquid nitrogen temperatures. This is a goal which has been pursued since the discovery of high-temperature superconductivity in 1986. In addition, this new wire technology may enable production of radio-frequency cavities and very high field magnets with larger volumes, leading to reduced energy consumption for DOE's high energy physics programs. Collaborative agreements are presently being negotiated with several companies for further research, development, and scale-up of this new technology for production of the long lengths of conductor needed for these applications. This new approach to conductor fabrication provides a firm basis upon which U.S. industry can compete with very active government and private industry programs in Europe and especially in Japan to develop conductors with characteristics comparable to those achieved at Oak Ridge National Laboratory. The U.S. market for HTS wires (only) was estimated in 1993 to be $200 million/year by 2010; the wires enable new electric systems with market size approximately ten times the value of the wire. The world-wide market for HTS wires may be as much as three times the U.S. market by 2010. A U.S. electric power system that uses HTS motors, generators, and transmission cables could save $5 billion per year, reducing losses in this type of equipment by up to 50 percent. These savings are due in large part to HTS wires with very small losses of energy, giving U.S. industry an enormous competitive edge over foreign companies.

AMTEX

This Subcommittee has heard of many of the fine technological achievements of DOE's national laboratory system. The national laboratories have been encouraged to work together to solve pressing national problems. I'd like to briefly review two initiatives that are under way and one that is proposed. The American Textile Institute (AMTEX) partnership with DOE began in 1994 and is now in its third year. Within DOE, this is a jointly-funded program by DOE's Office of Energy Research and Defense Programs. The focus is on five major areas: improved materials and processes; analysis, simulation, and computer integration; environmental quality and waste minimization; energy efficiency; and apparel automation. When this program started, the laboratory directors took it seriously enough to participate as a review committee. The AMTEX Partnership is an industry-driven, industry-led program. Federal agencies, national laboratories, and universities join with industry in this partnership. From an organizational viewpoint, AMTEX has shown that the DOE national laboratories can work together on a common industry-driven research agenda and produce meaningful, even revolutionary, results in a short period of time.

Most of the projects have just completed their second full year of operation, and the following results have been provided by the AMTEX Program Office. Electronic Commerce on the Internet: The Demand Activated Manufacturing Architecture (DAMA) project will help the industry define, develop, integrate and deliver an electronic marketplace system for all elements of the U.S. textile industry -- from fibers through retail. DAMA will enable companies to be more responsive to customer buying patterns and to reduce the nonvalue-added costs in the supply chain associated with excess inventory and inadequate forecasting. During FY 1996, the DAMA project will run pilot tests of new software tools that will enable companies in three levels of the supply chain (fibers-textiles-apparel) to share production and sales information in a secure manner. New modeling and simulation tools for evaluating on-shore versus off-shore production decisions will also be pilot tested. Also, a "National Sourcing Database," akin to an interactive Yellow Pages of suppliers, will be completed and demonstrated at a major trade show.

Dye and Salt Recovery from Textile Waste Water: Electrodialysis and filtration techniques for removing salt and dyes from textile waste water have been successfully demonstrated in the laboratory. Plans are under way to demonstrate these technologies in textile plants by October 1996. These technologies will provide both environmental and economic relief: companies to recover and reuse salt, dyes and water from waste water. Currently, 742 million pounds of salt are consumed and returned to the environment because no viable recovery method exists. Approximately 30 percent of the reactive dyes ($66 million in value) are now discharged in waste water. Annual water consumption of the industry in all textile processes is estimated at 133 billion gallons.

Fibrous Solid Waste Recovery: Techniques have been demonstrated in the laboratory for separating cotton/polyester fabrics into polyester and useful cotton-based chemicals such as cellulose acetate, which is used in photographic film. Demonstrations at industry facilities are pending. Each year, 237 million pounds of solid waste in knit fabric alone are generated -- costing the industry $474 million in lost materials and disposal fees.

On-line Fabric Inspection: Technologies for on-loom detection of defects in fabric have been successfully tested in production environments. Commercial equipment suppliers have been selected to receive licenses for these AMTEX-developed technologies. The first systems from the commercial suppliers for performing on-loom inspection will be provided to the industry partners this fiscal year. Systems for inspecting color printed patterns will be field tested in conjunction with both industry partners and commercial equipment vendors.

The greatest benefit from AMTEX will be its positive impact on the competitiveness of the fiber, textile and apparel industry — this translates into jobs saved and jobs created. Since AMTEX technologies are just now reaching the pre-commercial pilot testing phase, it is too early to say that AMTEX has saved jobs. However, creating and saving jobs is clearly among the expectations of the industry partners. In addition to the jobs created and saved directly, additional jobs will be created as companies begin to produce a new generation of textile processing equipment based on AMTEX-developed technologies. For example, the potential market for the on-loom inspection systems in the U.S. is approximately 70,000 looms. At a target price of $5,000 and a 50 percent level of implementation, these systems would create a $175 million new market for U.S. companies. Other AMTEX developments will also stimulate job growth by creating new products for U.S. manufacturers.

The industry partners in AMTEX are very pleased with the partnership and the results it is producing. It is safe to say that they would do AMTEX again and plan to continue their involvement. As evidence of their commitment to AMTEX, the industry program office estimates that between 80 percent and 90 percent of the nearly 100 industrial partners will renew their three-year commitments to AMTEX when they come up for renewal in the fall of 1996.

Environmental Management Sciences Program
During the May 1995 DOE laboratory directors' meeting, Tom Grumbly, then DOE's Assistant Secretary for Environmental Management, proposed involving the national laboratories in developing science-based solutions to problems faced by the

Environmental Management organization. We were pleased with this initiative, because the complexities faced by Environmental Management in cleaning up DOE's myriad legacy of contaminated sites over the next several decades will demand application of fundamental science and new innovative technology to difficult problems, and much of that science and technology has to come from research and development. Development of this knowledge base has not been within the scope of either the Office of Energy Research or the Office of Environmental Management. Devoting only a few percent of the Environmental Management budget, the largest single part of DOE's budget, to this basic science effort will result in many-fold returns on the investment. Because of the interdisciplinary nature of this effort and the fact that radioactive wastes must be dealt with, often in the field on DOE sites, use of the national laboratory system to spearhead this research makes good sense. The initial program, the Environmental Management Science Program, has been funded for FY 1996, the research needs and applied scope jointly identified by Energy Research and Environmental Management, and a call for proposals was issued by Energy Research. The Energy Research laboratories are partnering across the DOE system, with each other, academia, and industry, to provide the best of the nation's science and technology. Some of the key Environmental Management challenges include advanced characterization that accelerates treatment and immobilization of high-level wastes, characterization of wastes to permit recycling, characterization of hazards of landfills, emission-free destruction of organic wastes, and biomarkers and sensors of exposure to contaminated media. The process of winnowing down several thousand preproposals (including many from universities) to a more manageable number for peer review has occurred, and the review process is under way. If the present course can be maintained — that of funding fundamental science with an eye toward solution of future restoration problems, as previously defined in DOE basic research plans — while at the same time enhancing the funding base, this will be an excellent program for DOE and for the nation in providing new, cost effective solutions to environmental problems. I hope that as this program begins, its management would not be rich with oversight but would instead be more concerned with overall program direction as is typical of other DOE science programs.

Land mines

Land mines are a serious threat to our troops in Bosnia. Land mines are also a serious humanitarian problem throughout the world. According to the Department of State, there are an estimated 80,000,000 to 110,000,000 unexploded Land mines in 62 countries, and with millions of additional mines laid annually. Antipersonnel Land mines routinely affect civilian populations and kill and maim an estimated 26,000 people each year, or approximately 70 people each day. This is a significant technological problem on an international scale to which the national laboratories may be able to contribute solutions.

Representatives of some of the multiprogram national laboratories will be meeting tomorrow at Sandia National Laboratory to discuss the situation. We plan to explore the degree to which we might work together to form a Task Force on Land mines Detection. This is the kind of problem for which the DOE labs interdisciplinary approaches to problems has been effective. We may not have any solutions that have not yet been proposed or explored, but given the seriousness of the problem, we feel that we have an obligation to help solve it.

Biological Research
Biomedicine and biotechnology are likely to facilitate the most tremendous scientific revolution in the history of mankind. There is a proud history of biology at ORNL. In the 1950s, the Atomic Energy Commission (AEC) began research at ORNL to help understand the effects of ionizing radiation on humans. The mouse was selected as the subject of these experiments because it is the best mammalian genetic model available that is physiologically and anatomically similar to humans. For instance, we now know that over 90 percent of mouse and human genes have the same relative structure. ORNL has had many important breakthroughs in molecular genetics and protein engineering, including the discovery that the Y chromosome specifies the male sex in mammals. Another was the codiscovery of messenger RNA, the molecule that carries genetic information from DNA to the protein synthesizing apparatus in all cells.

Clearly, the DOE has been a leader in increasing knowledge of biological systems of both humans and other mammals. Several years ago when I was Director of the Office of Energy Research, I thought it appropriate that DOE begin a program to map the human genome, literally to produce a catalog of genes, and to map their position and sequence. The purpose of this proposed work was to gain a better understanding of long-term, low-dose effects from radiation or chemicals related to DOE's mission. The National Institutes of Health had a related strong interest in this goal of mapping the Human Genome. In the next decade, the Human Genome Program, cosponsored by DOE and the National Institutes of Health, will likely have met its objective of sequencing the 3 billion base pairs and mapping over 100,000 genes on the 46 chromosomes comprising the human genome. At that time, a critical scientific objective of locating human genes and disease regions will have been accomplished, but we will still know relatively little about the function of these genes. By analogy this is comparable to having the phone directory for Knoxville, Tennessee, which, coincidentally, has about the same number of personal phone listings as there are genes on the human chromosomes. One can use the phone book and learn the listing of the entries by name and street address -- this is comparable to knowing the names of genes and their locations on individual chromosomes relative to other genes, with the phone numbers being equivalent to the base pair sequences unique for each gene. What the scientific and biomedical communities need to know now is how do these genes function, i.e., what do they do for a living? This is the real value to be achieved from this basic research, if we are to eventually understand the genetic basis of human disease.

Going back to my analogy of the Knoxville phone book, the listings do not tell us much about what these people do to earn a living and the roles they play in interacting in their community. We can, however, call them up and ask them what their jobs are. The way we ask genes what they do is to turn them off or alter the way they normally function, and then look and see what goes wrong. As long as the genes are functioning normally, it is difficult to deduce their functional role in the body. If we block their function, we can observe the consequences and begin to understand how genes function through the proteins that they produce, which regulate cellular metabolism and development.

The way we turn genes off, or block their normal function, is to change them - or in other words, mutate them. This is where the DOE has a unique resource, a collection of some 200,000 mice that have been used in research since the early 1950's. They are a valuable national treasure and resource by virtue of the mutations they carry and the good record we have of the experiences they have been subjected to that has led to their present condition. The genetics operations at ORNL is making an important contribution to understanding gene function in mice – and humans. The mammalian genetics program, established nearly 50 years ago by the AEC to study the genetic effects of radiation, provided the scientific basis for radiation protection standards used today to protect human health. Now we are applying the remarkable similarity of the genes in mice and humans and the tremendous resource of over 1000 mutant gene lines maintained in several hundred thousand mice in the ORNL collection, to a new challenge. Many of these mouse mutations are similar to the genetically based afflictions of humanity. The mouse models of human disease which have been developed – such as those for polycystic kidney disease, diabetes Type II, cleft palate, sickle cell anemia, hydrocephaly, epilepsy, genetic-based obesity, and other immunological and neurological disorders – are proving of immense value in studying the genetic basis of human disease. Our use of the mouse as a genetic model brings half a century of knowledge and experiments — experiments that cannot be performed directly on humans — to understand how genes function in humans.

So what should be the next challenge? ORNL is proposing to study the gene and protein function, in particular, by using the mouse as a model organism. What should the objectives be of a leading gene function program? You've got to speed up the processes used to determine the function of genes and their expressed proteins by a factor of 1000, while reducing the costs. User facilities also need to be developed for collaboration with biomedical research centers and biological scientists, and for working with the pharmaceutical industry. ORNL is proposing a Gene and Protein Function Initiative. This is based on the proposition that DOE and ORNL are in a unique position to make major contributions to understanding the function of human genes by using the mouse as a model. Researchers in labs, academia, and industry see this as a significant next phase of the Human Genome Program. This initiative would accelerate the development of cures for genetically-based afflictions and diseases that affect mankind.

Summary

Each of the laboratories that you have heard from in the course of this hearing, and some of those that were not included today have unique capabilities. There is concern that because we have similar mission statements that we are doing the same things. One needs to examine our scientific output and productivity rather than our funding input. None of us would continue to receive funding through the Department of Energy if we were to merely duplicate the results of another lab. The program manager in DOE would not fund the work, if it were inferior or duplicative. While this isn't perfect insurance against no temporary similarity of work, it is close to perfect over any extended period. No scientist or engineer wants to have his or her paper rejected because it also shows what someone else published or presented a year ago.

Occasionally, questions have been asked concerning the national laboratories and about how their activities affect the average American. ORNL's motto is "Bringing Science to Life." The vignettes that I mentioned today all relate to those primary missions of research and development for which the national laboratories are uniquely suited, and to demonstrate how the products of these missions can improve the lives of our citizens through science and technology. Scientists and engineers have done a poor job explaining to the taxpayer how government-funded basic and applied research and development have been of enormous value to them. We must do a better job of communicating our value if we expect to continue to receive the funding that we have. But even though we have done a poor job of communicating, it would be cutting off our nation's nose to spite its face if we were not to continue the programs that have given the United States the technical tools to be the leading nation that it is.

Chairman ROHRABACHER. I appreciate your testimony. We will have some questions about that later. Thank you very much.

Dr. Shank.

STATEMENT OF DR. CHARLES V. SHANK, DIRECTOR, LAWRENCE BERKELEY NATIONAL LABORATORY, BERKELEY, CALIFORNIA

Dr. SHANK. I am privileged to have the opportunity to talk to you today about the 1997 request for the Department of Energy's Office of Energy Research. As you are well aware, the Office of Energy Research supports peer-reviewed, world-class fundamental research at the Department of Energy's national laboratories and universities.

And, I am going to focus my remarks on three specific areas that are important to us at the Lawrence Berkeley National Lab. The first is the Scientific Facilities Initiative.

This was—the 1997 request continues this Scientific Facilities Initiative at a somewhat lower level. I strongly encourage the Committee to continue the support and, if possible, provide some mechanism for equilibrium with what we were able to have in 1996, realizing the difficulty of that.

It has had an enormous impact in our laboratory where we operate the Advance Light Source, the world's brightest source of soft x-rays. The Initiative has meant a 78 percent increase in scheduled user time. We have gone from nine shifts to 16 shifts. It has had an enormous impact on the vitality of our scientific program.

We also operate the National Center for Electron Microscopy And, in that facility, which serves universities and industry and Department of Energy programs, we have seen a 30 percent increase in available user time.

My second issue is the support of the Mathematical, Information and Computational Sciences program. We are the home of the National Energy Research Scientific Computing Center, referred to a NERSC.

And, this is one of the largest computing capabilities in the country which is non-classified. It serves over 4,500 researchers at national laboratories and universities and industries doing work wit the Department of Energy.

It covers programs from materials science to medical imagin and combustion. And, it is a very dynamic program. And, it's on that will keep us at the forefront of computing in generations i both hardware and software in the future.

A new component has been added to the 1997 budget. It is calle the DOE 2000 program.

I would like to offer my support for that program. It's going provide a really unique opportunity for us to utilize the faciliti like the Light Source and others at a distance.

We are going to create, using the Internet, the capability to actu ally use and having the touch and feel of these instruments. Ima ine being a professor at the University of Wisconsin, sitting in you office and being able to do work in California. You will be able stay in snowbound Wisconsin and not have to go to Berkeley to b able to perform your research.

Finally, I would like to talk about the Human Genome Program. It's to the Department of Energy's credit that it had the vision and the wisdom to begin this project in 1987.

Berkeley was one of the three central laboratories and original centers in that activity. There has been an enormous amount of progress to cost effectively sequence the 3 billion base pairs that really are the blueprint that makes up man.

We are making enormous progress. Our laboratory has contributed 5 billion base pairs to the gene bank. This places us second in the world in total number of pairs sequenced.

And, we have become very cost effective, reducing that cost to currently 50 cents per base pair. This is one of the most cost effective efforts in the world today.

We expect to increase it and become more cost effective. And, we are at a time right now where we have developed technologies which are ready for a large scale up.

And, in the budget is a $7.9 million request for high throughput sequencing. We strongly support that.

Finally, I would like to conclude by thanking you for the opportunity to talk about the Office of Energy Research programs.

[The prepared statement of Dr. Shank follows:]

Written Testimony of Dr. Charles V. Shank
Director, Lawrence Berkeley National Laboratory
before the
House Science Committee
Energy and Environment Subcommittee
May 8, 1996

Mr. Chairman, thank you for this opportunity to testify before your Subcommittee on the FY 1997 budget request for the Department of Energy's Office of Energy Research (OER). The OER programs support world-class science at DOE national laboratories and universities. I am pleased to endorse the overall budget request, which provides support for fundamental research consistent with both the wishes of both Congress and the Administration.

Before I address the topic of today's hearing, I think that it is important that the Members have a sense of the Lawrence Berkeley National Laboratory. We are the first of the DOE laboratories, established in 1931 and located in the hills above the University of California, Berkeley campus. Our FY 1996 total budget is approximately $340 million, including both operating and construction, and we employ approximately 3,500 people. Our research spans the DOE spectrum from high energy physics and high performance computing to materials and biological sciences and energy-efficiency. We also do research for a number of private and public institutions, and are the largest DOE performer of research for the National Institutes of Health.

Since our inception, we have been managed by the University of California, and our successful research record over the last six decades reflects the University management and involvement. Today we have over 250 scientists at the Berkeley Lab who are faculty members on the University of California Berkeley, Davis, San Francisco and Riverside campuses. We also have over 500 graduate students earning their masters and doctoral degrees through their performance of research at Berkeley Lab. This level of university involvement, unique within the DOE system, has provided a high level of quality scientific performance and leadership that should be a model for future Federal laboratory operations.

I want to focus my remarks today on three specific areas within the Office of Energy Research that are critically important to the research at Berkeley Lab:

--- the Scientific Facilities Initiative,

--- the Mathematics, Information and Computational Sciences program, and

--- the DOE's human genome program

First, the FY 1997 budget request continues support, albeit at a slightly lower level, for the Scientific Facilities Initiative (SFI). This effort to provide adequate operating and capital support for DOE's unique, world-leading facilities was proposed in the FY 1996 budget request, and was enthusiastically supported by the Congress. I would strongly encourage the Committee to continue its support for this Initiative and, if possible, provide the additional funds necessary for these facilities to operate at their FY 1996 level.

Let me outline for you briefly what this additional support has meant at Berkeley Lab. At the Advanced Light Source (ALS), the world's brightest source of "soft" x-rays, the Initiative has meant an increase of 78% in the scheduled user time, from nine to sixteen eight hour shifts per week. The ALS has also expanded its level of user support by doubling, from seven to fourteen, the number of User Program Staff.

Full exploitation of the state-of-the-art capabilities of the ALS requires not only adequate operating hours, but also a comprehensive array of beamlines equipped with experimental stations. The SFI allows us to continue our steady progress toward the goal of a fully-instrumented facility with the construction of three new beamlines. Two of these will be applied in part to gathering fundamental information about magnetic materials, such as those used in computer disks. At the first of these beamlines, scientists will use ultrabright beams of circularly polarized x-rays to examine how atomic properties give rise to magnetic materials. With the same beamline, we will also look at several important biological enzymes containing metals that play key roles in cellular processes, such as photosynthesis in plants and reduction of the oxygen we breathe to a usable form.

The second additional beamline will also have two functions. In one role, it also use circularly polarized x-rays, but here the emphasis will be on imaging areas with different magnetization that occur within magnetic materials, thereby leading to a deeper understanding of the influence of microstructure on overall magnetic behavior. In the other role, researchers will use the beamline to obtain chemical information about microstructures both natural and artificially engineered, such as patterns on computer chips.

The third beamline from the SFI is an infrared, rather than x-ray, beamline. Research will center on the important wavelength range where many organic materials exhibit unique absorption signatures. Subjects of current interest include thin films of polymers, the interfaces between polymers or between polymers and other materials, and the identification of organic particles, such as contaminant particles on the silicon wafers used in microchip manufacture.

Berkeley Lab also operates the National Center for Electron Microscopy (NCEM), which provides a unique collection of electron microscopes and support facilities for many different energy research programs. The facility annually serves about 100 scientists and as many research programs from across the U.S. Roughly 50% of the users are supported by DOE programs, 25% by the National Science Foundation, and the remaining 25% by industry, the Department of Defense, foreign and other grants. As a direct result of the SFI, the NCEM has established two new positions to provide access to the facility for scientists who are not expert microscopists. These scientists collaborate with a number of external users to apply state-of-the-art expertise and instrumentation to significant materials problems.

Initiative funds are also being used for a major refurbishment of the unique 1.5 MeV High Voltage Electron Microscope (HVEM), the nation's highest voltage microscope. The improved performance of the instrument is expected to be of major benefit for the user community. The current development of a remote interface for this instrument will make this the first HVEM accessible on-line from remote locations.

When this major refurbishment is complete, NCEM expects to provide approximately 30% more operating hours to its users than were available before the Facilities Initiative.

At Berkeley Lab's 88-inch cyclotron, nuclear physicists from around the world come to do research using its beams of low-energy heavy ions to look at atomic nuclei under unique conditions. The SFI will mean an increase of 18% in its operating hours for FY 1996. This will allow scientists to take advantage of the new Gammasphere detector, which is the most powerful detector of its type in the world for the study of nuclear structure.

My second issue of concern is support for the DOE FY 1997 request for the Mathematical, Information and Computational Sciences program. This exciting program provides support for advanced mathematical and computational research, including the communications and information infrastructure necessary for computing-based fundamental scientific research.

Berkeley Lab is proud to be the new home for DOE's National Energy Research Scientific Computing Center (NERSC), the largest unclassified scientific computing resource on the West Coast. NERSC serves over 4,500 researchers from national laboratories, universities and industries across the nation as they work on scientific programs from materials science to medical imaging. As our computing world changes almost daily, NERSC will also be in the forefront of the development of future generations of scientific computing hardware and software.

A new component of this program in the FY 1997 budget proposal is support for the DOE 2000 program. This joint Energy Research-Defense Programs effort will, among other things, develop a common technology base that will someday allow scientists to access and use unique facilities like Berkeley's Advanced Light Source through the Internet - without having to travel. When this effort is fully operational, it will revolutionize the ability of the scientific community to achieve the maximum value from these user facilities. I hope that the Committee will recognize the importance of this effort and support the DOE 2000 program.

Finally, I want to touch on one additional program within the Office of Energy Research. The human genome project is perhaps the most important scientific enterprise in the history of the life sciences, and it is to the Department of Energy's everlasting credit that they had the vision and wisdom to begin this project in 1987. Berkeley Lab was one of DOE's three original genome centers, and great progress has been made in advancing the science and technology so that we can cost-effectively create a sequence of the three billion base pairs of genes that are the blueprint of man. To accelerate this effort, we will be completing at the end of 1997, on time and on budget, the construction of a new 40,000 square foot laboratory to bring together the now-dispersed elements of this multidisciplinary program.

The research progress in making gene sequencing both cheaper and faster has been so dramatic that we are now ready to take a major step forward and accelerate human gene sequencing. Berkeley Lab has just completed innovative sequencing for a milestone of five million base pairs. This achievement places it second in the world in total pairs sequenced. More importantly, our technical innovations have reduced costs to fifty cents per pair sequenced, one of the most cost-effective efforts in the world. We are therefore excited that the DOE FY 1997 budget request proposes an increase of $7.9 million for high-throughput sequencing of human DNA. We strongly support this request as the first step in aggressively moving to complete the genetic map of man.

Although begun by DOE, the genome project has in recent times been a collaborative effort with the National Institutes of Health. Berkeley Lab, in collaboration with UC Berkeley, has recently received a major NIH grant to apply the directed sequencing strategy developed for the human genome to produce the genetic sequence of the fruit fly. The fruit fly is a model organism analogous to the human system, which will allow scientists to study and modify its genetic structure for the future benefit of humans.

Let me conclude by thanking the Subcommittee and the Department of Energy for their support of the research supported by the Office of Energy Research. I believe that it is of the highest quality and is a major investment in this country's economic future. I hope that you will continue to be as supportive, and I would be happy to answer any questions.

Chairman ROHRABACHER. Thank you very much. Dr. Madia.

STATEMENT OF DR. WILLIAM J. MADIA, DIRECTOR, PACIFIC NORTHWEST NATIONAL LABORATORY, RICHLAND, WASHINGTON

Dr. MADIA. Thank you, Mr. Chairman, members of the Subcommittee and, in particular, Mr. Hastings, for that very generous introduction.

I am going to talk this morning about some of the basic research programs at Pacific Northwest National Laboratory. At Pacific Northwest, we are at our core mission an environmental science and technology laboratory.

And, as such, the basic research investment that this Committee makes in Pacific Northwest is both linked and leveraged application funding that we find, first, throughout DOE and other federal agencies and the private sector. Our core mission, being environmental science and technology, has direct and relevant near-term application.

At Hanford, as Doc Hastings mentioned, we have one of the world's largest environmental problems. Just to give you an example, at Hanford we have 177 one million gallon high level nuclear waste tanks in the ground.

Current estimates——

Chairman ROHRABACHER. Would you say that again?

Dr. MADIA. One hundred seventy-seven one million gallon each high level waste tanks in the ground. Current estimate to clean up just the tanks at Hanford alone runs between $20 billion and $40 billion.

The focus we have at Pacific Northwest is to develop innovative science solutions to bring down those costs substantially. The reason in this country our environmental cleanup legacy will run us several hundred billion dollars at Hanford and Oak Ridge and other places is because the technology we are planning to use to do the cleanup is 10 to 20 years old and grossly inadequate to deal with these issues.

At Pacific Northwest, the investments you are making in basic research are going to find new and novel solutions to drive down those cleanup costs. In the area of separations, for example, those tanks, Mr. Chairman, that I mentioned, have less than one-tenth of 1 percent of their constituency that is highly radioactive or hazardous.

If we could separate those materials, which are rather dangerous from the rather benign materials, we could materially drive down those costs. Here's an example. And, the budget account for these activities is biological environmental research.

In the BER funding, we directly connect those basic fundamental research programs to applications programs that, in the next 5 to 10 years, we expect to see substantial cost reductions as a result. You asked repeated questions throughout the morning about applications of fundamental science. This is an exact example of doing that.

The cornerstone for our strategy at Pacific Northwest is the Environmental Molecular Sciences Laboratory. It will be completed this year, assuming the $35 million capital funding remains in the budget request.

EMSL will be the premiere environmental laboratory in the world when it's opened next year. State-of-the-art instrumentation to do the characterization necessary is built into that facility, again aimed directly at those kinds of programs.

We take this basic research investment that you are providing and we couple it with applications investments out of DOE's environmental management program, out of DOD programs, out of EPA programs. And, with private industry, when we get to the applications end, link and leverage the basic science investment with the applications to bring those solutions to bear.

The last point I will make is a strong point of support for the global change research component of the BER budget. Now, I know this is a politically charged and scientifically charged issue——

Chairman ROHRABACHER. I don't know why you would say that.

Dr. MADIA. It is our strong opinion that we do not know, as scientists, enough information to make the kind of policy decisions we are talking about regarding global climate change research. We simply don't have the information.

And, the potential consequences of these decisions are so substantial that it's our position we must be highly vigilant in supporting this budget to develop the basic science understanding, the basic chemistry and the basic physics of how clouds and aerosols and the oceans interact and affect our environment. We simply don't have that information.

And, we strongly support and encourage this Committee to continue the global change research component to this budget. Thank you very much.

And, I will be glad to answer any questions you may have.

[The prepared statement of Dr. Madia follows:]

Written Testimony

of

Dr. William J. Madia
Director
Pacific Northwest National Laboratory

Energy and Environment Subcommittee
of the House Committee on Science

May 8, 1996

Washington, DC

Mr. Chairman and Members of the Subcommittee:

My name is William Madia and I am the director of the Pacific Northwest National Laboratory located in Richland, Washington. Our core mission is to deliver relevant and productive environmental science and technology to critical national needs. We also apply our capabilities to meet selected national security, energy, and human health needs. I am pleased to be here today to discuss my laboratory's role in the Department of Energy's Office of Energy Research programs and the Scientific Facilities Initiative. I have organized my testimony around five main points.

1. The Office of Energy Research conducts programs that are a vital part of the nation's basic research investment.

The Office of Energy Research (OER) invests in basic research in support of the Department of Energy's Science, Environment, Energy, and National Security Missions. These investments lead to enhanced scientific knowledge and new technologies that result in substantial benefit to the Nation. OER is the third largest source of support for basic research after the National Science Foundation and the National Institutes of Health.

The Office of Energy Research has a clearly distinct and essential role in our basic research enterprise:

- The Office of Energy Research is our primary source of support for high energy and nuclear physics, and supports unique, highly successful programs in selected fields of chemistry, the life sciences, the earth and environmental sciences, mathematics and computer science. OER also supports major interdisciplinary programs in areas like materials science and the application of high performance computing to the modeling of complex natural and engineered systems. Coordination with other agencies that support fundamental research is carried out through both the National Science and Technology Council and direct communication at the program level. This assures that the OER portfolio is not duplicated by work supported elsewhere.

- The Office of Energy Research constructs and operates a set of highly complex scientific user facilities, bringing sophisticated and powerful research tools to the entire U.S. research community. These facilities provide capabilities in areas such as materials characterization or determination of the structure of complex biological molecules that simply

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would not be otherwise available to university or industrial researchers, and which are essential to U.S. leadership in science and technology.

- The fundamental research supported by the Office of Energy Research is directed towards providing the knowledge necessary to meet specific, high priority national needs. Such mission-oriented research is essential if we are to clean up our nuclear waste sites at reasonable cost, meet our future energy needs while protecting our environment, or provide for the national security in our rapidly changing world. I believe that OER is clearly among the most effective funding agencies in linking science to technology that addresses national needs.

I'd like to make three other general points regarding Office of Energy Research programs. First, the Office of Energy Research budget **supports a substantial volume of academic research**, carried out at universities across the country. At the Pacific Northwest National Laboratory alone, we engage in formal scientific and educational collaborations with faculty and students from more than two hundred colleges and universities across the country, indeed around the world. Second, through student and postdoctoral fellowships at the national laboratories, and through its user facilities, the Office of Energy Research programs play a major role in the **development of the next generation of scientists and engineers**. Each year thousands of students conduct research at the national laboratories and at the DOE user facilities thus helping assure that our Nation will have the necessary scientific leaders for tomorrow's more technically complex world. Third, the **quality** of the science supported by the Office of Energy Research programs **is among the best in the world**. Rigorous and extensive peer review is the norm in selecting and managing the Department's research programs, whether conducted at the national laboratories or at our universities. Individuals numbered among the nation's most distinguished scientists serve on the advisory panels that guide operation of the Department's major scientific facilities and programs.

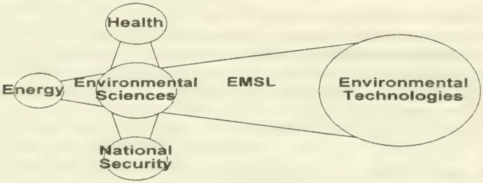
I believe that all of the Office of Energy Research programs continue to merit the strong support that both this Committee and Congress as a whole have traditionally provided for our national investment in basic research.

2. The Biological and Environmental Research program supports fundamental science directly applicable to critical national needs.

In keeping with Pacific Northwest National Laboratory's focus on our core mission of environmental science and technology, I'd like to focus particular attention on the Biological and Environmental Research account.

Our Core Mission

Environmental Science and Technology



The Biological and Environmental Research budget supports basic research that is yielding the scientific advances necessary to resolve some of our nation's most pressing environmental and health issues. I'll speak to three of those issues here.

Discovery of affordable solutions to the seemingly intractable environmental cleanup challenge at DOE sites requires new science.

As a nation, we simply can not afford the cleanup bill for DOE's and other hazardous waste sites using the best available technologies of today, nor do those technologies provide even marginally satisfactory solutions to some of the most critical and complex cleanup challenges. Our experience has shown that to achieve the necessary dramatic improvements in cost and risk we must have a much deeper scientific understanding of the processes that govern contaminant transport and fate in the subsurface environment. Biological and Environmental Research Programs are providing that fundamental knowledge. For example, continuing investments in leading-edge subsurface science are providing the knowledge base required to cost effectively remediate groundwater contaminated with hazardous radioactive and chemical wastes. This research, along with investments in the life sciences, is providing the basis for a new initiative to take advantage of naturally occurring microorganisms in subsurface systems for treatment and stabilization of contamination. This process, commonly referred to as bioremediation, will come to be recognized as a real breakthrough not only for the cleanup of DOE's sites but for solving environmental problems around the world. The Natural and Accelerated Bioremediation Initiative (NABIR), part of the Fiscal Year 1997 budget request, will support breakthrough research in bioremediation of soils and groundwater.

Biological and Environmental Research funding has supported the scientists who have discovered and described fundamentally new microbial communities in the deep subsurface where it was previously believed that life did not exist. Not only has this resulted in potential for innovative, cost-effective biological means for restoring contaminated soils and groundwater, the work has revealed the existence of subsurface ecosystems with characteristics that provide clues about the origin of life on earth. I'm proud to say that the Pacific Northwest National Laboratory plays a key role in these and other of Biological and Environmental Research programs, which support what we believe to be among the most scientifically fruitful research efforts in the laboratory.

The transition to risk-based environmental management depends on understanding the molecular-level mechanisms for damage to human health.

Like the Office of Energy Research portfolio as a whole, the life sciences portion of the Biological and Environmental Research program plays a distinct and important role in our overall health-related research efforts. OHER has a major role in the Human Genome program that is providing the fundamental knowledge that is already supporting major developments in our understanding and treatment of a variety of serious diseases. Medical applications research, in spite of the name, provides the fundamental science underlying, for example, many of the astonishing advances in the use of radioactive materials to treat cancer.

OHER is giving increasing emphasis to understanding of health risks from exposure to contaminants produced in energy production and use, as well as those from our national security programs. In my opinion this effort is exemplary in two respects. First, it builds on new tools developed in the Human Genome and Molecular and Cellular Biology programs to establish the molecular basis for health effects. This is a far more powerful scientific approach than has previously been available to us. Second, the programs will yield exactly the kind of scientific knowledge required if we are to make the highly desirable transition from our current regulatory approaches to risk-based regulation.

At Pacific Northwest National Laboratory, our genome and health effects research emphasizes the study of the molecular level mechanisms by which hazardous physical and chemical agents affect living systems. Recent contributions include partial elucidation of the molecular mechanisms responsible for repair of chemically induced DNA damage and development of large molecule mass spectrometry techniques that, among other applications, have the potential to form the basis for very high speed gene sequencing.

If we are to avoid expensive and potentially catastrophic policy mistakes, we must dramatically improve our understanding of climate on both global and regional scales.

The most critical aspects of future energy technology deployments will be their health and environmental impacts. Climate change and other global-scale environmental issues pose some of our most challenging, and politically charged, policy decisions. In my judgement this is an area where it is absolutely essential that we have the very best possible science at our disposal. If we are to make the right policy choices we simply must improve our fundamental understanding of the very complex dynamics of our climate. Although we have achieved a good general understanding of the drivers that affect climate, the state of our knowledge is far from satisfactory. Simply put, we just don't know enough to predict the likelihood, extent, or consequences of change sufficiently reliably and in sufficient detail to support sound policy decisions. Those on either side of the argument who say we do know enough are simply uninformed. Given that the potential consequences are so great, we must not allow this condition to continue.

Office of Health and Environmental Research programs are playing a valuable role in providing that fundamental understanding. Research is directed at better understanding the interaction of radiation with clouds, aerosol particles, and other constituents of our atmosphere, which are some of the primary sources of uncertainty in our ability to model the earth's climate. OHER also supports efforts to substantially increase the predictive power and resolution of climate models through the application of advanced computing technology. These and other OHER programs will provide much of the scientific basis for regional prediction on decadal and century time scales. This effort is essential to answering the very specific questions that must be the basis for policy decisions. It is at least as important to know whether it's likely that there will be, say, enough rain to grow corn in Nebraska as it is to predict the average global temperature. Practical regional-scale prediction is very challenging indeed, but we are making progress.

Again, let me emphasize that although there is honest disagreement over the magnitude and impact of human effects on our climate, our scientific knowledge has reached the point where it is absolutely clear that we must be vigilant on these issues.

Pacific Northwest participates extensively in global change research supported by the Office of Health and Environmental Research. I'm particularly proud of our major role in the Atmospheric Radiation Measurements program, which includes overall program management and scientific direction. We and our collaborators have created a world-class experimental facility that allows the testing of key elements of general circulation models in unprecedented detail. This work is central to improving the predictive power and reliability of these models, which are our primary scientific tool for investigating climate change. This program is providing an unprecedented wealth of detailed information on the interaction of radiation with clouds and aerosols that will reduce one of, if not the, largest scientific uncertainties in our understanding of the earth's climate.

3. The Scientific Facilities Initiative is essential to the health of the nation's scientific infrastructure.

I strongly support the Scientific Facilities Initiative (SFI) because it will enable DOE to significantly increase the availability of its unique user facilities to the general scientific community (academia and industry) and its researchers at the national labs. User facilities such as the synchrotron radiation laboratories, neutron facilities, the Combustion Research Facility and the soon to be completed Environmental Molecular Science Laboratory (EMSL) at Pacific Northwest serve two key functions. First, they are important in maintaining U.S. leadership in science. Research conducted as we design, build, and equip major user facilities involves development of instrumentation that goes well beyond the state-of-the-art and serves to define world scientific leadership in many areas. The ultra-high frequency Nuclear Magnetic Resonance instrument under development for the EMSL is an example. Many scientific disciplines, including chemistry, materials science, structural biology, and the geosciences, depend on these unique resources for much of their cutting edge science. Second, these facilities are extensively used by many researchers from the laboratory system, academia, and industry in support of other enduring federal mission such as environmental management, future energy supply, and national security. The facilities are also extensively used for both basic and, on a cost-reimbursable basis, proprietary research by scientists in the electronics, semiconductor, chemical, pharmaceutical, and other industries that depend on advanced science and technology to maintain market leadership.

Funding for the Scientific Facilities Initiative will directly benefit the work being conducted at Pacific Northwest National Laboratory. We use the various DOE user facilities to conduct programmatic research. Funding under the Initiative is improving existing user facilities by providing more operators, improving the technical performance of the facilities and expanding the hours of operation. In partnership with a consortium of Northwest universities, we have a proposal pending to the Initiative to complete construction of a dedicated beam line at the Advanced Photon Source. This beam line is specially designed to support the environmental missions at our laboratory. Finally, we are just completing construction of the Environmental Molecular Sciences Laboratory, and will begin initial operations as a user facility in 1997. Scientific Facilities Initiative funding or its equivalent will be essential to maintaining this laboratory at the state-of-the-art.

4. The Environmental Molecular Sciences Laboratory is bringing remarkable new scientific capabilities to bear on our pressing environmental challenges.

We're in the final stages of construction on the Environmental Molecular Sciences Laboratory (EMSL) at Pacific Northwest, and are very excited about initiating operations at this new user facility next year. Funding for completion of the construction project and initiation of operations is included in the Office of Energy Research budget request.

The Environmental Molecular Sciences Laboratory will be the Biological and Environmental Research's first major facility, and the most advanced environmental laboratory in the world. It will focus the attention of the nation's research community to the solution of DOE's highly demanding cleanup challenge. Research conducted in the Laboratory will focus on developing a molecular-level understanding of the physical, chemical, and biological processes that underlie environmental remediation, waste processing, and health and ecological effects. To address the challenges posed by the complex physical, chemical, and biological systems found in the environment, the Laboratory will capitalize on today's revolution in the experimental, theoretical, and computational molecular sciences. The tools of modern molecular science, aggressively applied by our nation's best scientific talent, offer the promise of enabling cleanup at acceptable cost, with known risk, and in a reasonable period of time. Again, I am convinced that without new science we simply can't get this job done at reasonable cost and acceptable levels of risk.

But the Environmental Molecular Sciences Laboratory will have impacts that go far beyond DOE's environmental mission. As a user facility, it will provide unique scientific instrumentation to the nation's entire scientific community.

Let me describe just two of the several research facilities to be housed in this laboratory. We and our collaborators are developing the world's most powerful nuclear magnetic resonance instrument as the cornerstone of the Magnetic Resonance Facility. In addition to the world's first ultrahigh frequency (900 to 1000 megahertz) nuclear magnetic resonance spectrometer, the facility will also include a state-of-the-art 750-megahertz nuclear magnetic resonance spectrometer and other supporting information. It will provide unprecedented capability to study the molecular structure of biomolecules, both as they relate to bioremediation processes, and to obtain a better understanding of contaminant effects on human health. It is already clear that the ultrahigh frequency instrument will be among those in greatest demand when user facility operations begin.

From the beginning of the EMSL, we made a conscious decision to take advantage of the revolution that is occurring in computers today. This decision led to the establishment of the Molecular Science Computing Facility. This Facility will be used to help design of new materials to separate radioactive waste from tanks, to investigate contaminant transport in the subsurface, for rational redesign of enzymes for in situ accelerated bioremediation and for the investigation of DNA damage and repair mechanisms.

A fundamental understanding of molecular level processes is required if we are to develop the most cost-effective environmental remediation and waste management technologies. In order to make realistic predictions about complex systems, scientists are turning to the use of computers to address more and more complex questions. High performance computers can be used to solve the complex mathematical equations that represent our best understanding of natural phenomena inaccessible to experiment. Just as the nuclear weapons "Stockpile Stewardship" effort is turning to the use of computational science because of testing bans, so are the other scientific and technology areas such as chemistry, biology and physics turning to computational science to help gain a better understanding of natural phenomena.

In order to be at the forefront of the high performance computing revolution, we require both a robust high performance computing system and advanced scientific software capable of making use of that system. We are acquiring the most powerful system ever sold by IBM, indeed one of the few most powerful computing systems available in the world today. In order to get the optimal performance from this parallel computing system, a whole new generation of software has had to be developed. As part of the EMSL project, we are developing scalable and portable computational chemistry computer codes for massively parallel computer systems. Pacific Northwest National Laboratory is widely recognized as the world leader in high performance computational chemistry software. Support for the Facility and the underlying software technology is included in the EMSL project and under the Computational and Technology Research program, while our Theory, Modeling, and Simulation program is supported through the Basic Energy Sciences Chemical Sciences program.

5. The scientific quality, productivity, and value to the nation of the Office of Energy Research funded programs at each of our Laboratories is demonstrably high.

Let me give just a few examples from ongoing work at Pacific Northwest National Laboratory funded through either the Office of Basic Energy Sciences or through the Office of Biological and Environmental Research.

Recent advances at our laboratory in near-field fluorescence microscopy make it possible to conduct single-molecule spectroscopy at the nanometer scale in an ambient environment. This June, Sunney Xie of our staff will receive the 1996 Coblentz Award, which recognizes outstanding achievement by a young molecular spectroscopist for this work. This research is expected to have a major impact on the understanding of biochemical processing in biological membranes, and has applications in chemical analysis, materials, and the mapping of biological structures.

I said earlier that the Office of Energy Research basic portfolio was unique in its focus on the science necessary to support DOE missions, and that OER is highly successful in making the linkage between science and technology. One way in which we measure the long-term impact of basic research work at our Laboratory is by the number and value of the new technologies that are deployed that have their basis in our scientific work. Among the several recently deployed technologies for which we have received either R&D 100 awards for best new technologies or Federal Laboratory Consortium awards for technology transfer include our ultrasonic microstructural analyzer and the Electrical Remediation of Contaminated Environments or ERACE process,. Numerous technical advances that have arisen from our Basic Energy Sciences supported materials science work include potentially improved bone implants, specialized ceramic materials for a number of applications, corrosion-resistant coatings, advanced sensors, and coatings for specialized optical systems.

I also said earlier that the quality of the Office of Energy Research programs is validated by extensive and rigorous peer review. This is particularly true of major projects such as the Environmental Molecular Sciences Laboratory. This January a twenty person review team with representatives from DOE, academia, and other National Laboratories conducted a full review of the EMSL project, covering both progress on the construction project and two major research programs. Here are two excerpts from the programmatic reviews:

- "Scientific work already being performed in Theory, Modeling, and Simulation (TM&S) is first rate and the scientific directions have been well chosen....The EMSL TM&S team is building a first rate parallel system and performing sound software engineering."
- The EMSL Macromolecular Structure and Dynamics (MSD) team is conducting top quality scientific research and contains a strong core of physical scientists..."

Closing

I wish to thank the committee for providing this opportunity to review the results of your investment in the Office of Energy Research portfolio, and in Pacific Northwest National Laboratory.

I began this testimony by saying that the programs funded through the Office of Energy Research budget are a vital and productive part of the nation's basic research investment. I hope that the examples I've cited today convincingly illustrate the high value of this investment. The DOE scientific user facilities are essential to U.S. leadership in critical areas of science and technology, from materials sciences to biotechnology. Across the OER portfolio the peer-reviewed scientific research supported by OER at our universities and at the national laboratories is of outstanding quality. This research is directly relevant to pressing national needs from environmental cleanup to understanding climate change to energy utilization. It is delivering dramatic scientific breakthroughs that are the foundation for new and impactful technologies. In my judgement, the nation's scientific and technical return on the investment made in these programs is among the highest in our entire research portfolio.

I strongly believe that your continued support for the Office of Energy Research's portfolio is in the long-term best interest of American.

Chairman ROHRABACHER. All right. Well, thank you. Is it Madia?

Dr. MADIA. Madia.

Chairman ROHRABACHER. My apologies. You know, with a name like Rohrabacher, I should be getting everybody's last name straight but I never do. And, I apologize for that.

Let me get down to some basics. And, Dr. Madia, you made two points.

You know, you have these 177 containers with all of this hazardous material there. And, it's very—who can—who would ever deny that trying to find some basic research to find ways of dealing with that problem is not a benefit? No one. I don't know anyone who would deny that that's to the benefit of our country.

Now, we've got to make a choice here. We've got limited resources.

And, we are trying to balance the budget for future generations. We think our economy will be stronger if we do that. So, we set this goal.

And, the other part of your presentation was global warming research or weather research and changing. And, you know, it seems to me you have made your point very well on one and then you just sort of threw the other one out.

But, you do realize that the money that's going for—that if we do both, that they are going to feed off each other. One isn't going to receive the same amount of money if you pay for both.

Dr. MADIA. I understand that.

Chairman ROHRABACHER. All right. And, you would still think that that's the——

Dr. MADIA. The consequences in both of these areas is unacceptably high. We cannot leave 177 high-level nuclear waste tanks sitting in the ground in Richland, Washington nor can we take the chance of not understanding the consequences of China and Taiwan and Asia putting on line nearly 100 fossil-fired coal plants, dumping an enormous amount of carbon dioxide into the atmosphere and potentially catastrophically changing—potentially catastrophically changing our climate patterns.

My point there is. I'm not saying it will change them. I am saying we don't know.

And, the consequences are potentially far too high to take that risk.

Chairman ROHRABACHER. But, we know we have got this threat right there with these 177 containers.

Dr. MADIA. Yes.

Chairman ROHRABACHER. And, we know that that just represents, you know, one of—I mean, if you take a look at all of the environmental threats that face us and we can actually see these things that if, indeed, physics and fundamental research can help us go to the molecular structure and help break down some of these threats, then we know those are threats.

Dr. MADIA. Yes.

Chairman ROHRABACHER. So, doesn't that—wouldn't that necessitate a decision that would be totally weighted in the direction of finding the known threat rather than trying to find out more about a potential threat?

Dr. MADIA. Given the consequence of the potential climate threat, our position strongly is you must do both.

Chairman ROHRABACHER. Okay. We have—I would like to ask you each a question. And, it's the same question, but we just—this would be just for the record.

President Clinton's balanced budget plan calls for a sharp decrease in funding for high energy and nuclear physics beginning in 1998 and then increases again in the year 2001 and 2002. Does this make budget sense to you?

And, would you rather have instead a steady amount of money allocated over a period of time?

Dr. MADIA. Let me start. With respect to that question, scientists and engineers need stability in their life. They don't do well—we don't do well with all this uncertainty.

And, we have lived in a tumultuous two year period. That destabilization about their future and their future funding destroys the innovation process in a laboratory.

So, stability and surety is much more important than the absolute number. We have to have stability in our lives.

Even if we talk about only losing 50 more scientists out of our laboratory, the full 4,000 think it's them. And, they worry about that until the final decisions are made. And, it destabilizes the entire laboratory.

Chairman ROHRABACHER. Okay.

Mr. SHANK. We heard from Dr. Krebs some question about what the real meaning of that projection is. The consequences of that projection would be to do serious harm to science and, in particular, science in our laboratories.

I am quite concerned about it. I know from my 20 years of experience during the days when AT&T Bell Laboratories was a very stable place, the number one thing that I thought that led to the success of that lab was stability and funding, the ability to make a prediction to take a long-term view.

We are now all feeling that we are right on the precipice. We might survive this year, but the next year we might slide down.

I think it's very difficult to think in the long term and bring value to the future with such a great uncertainty in planning for our future.

Dr. TRIVELPIECE. I think it's said well, that stability, continuity and predictability in this area is important. And, the two things that my colleagues didn't touch on that maybe I will catch, one is that if you have a roller coaster effect in funding what happens is that people will be attracted to a field that looks like it's about to grow.

Some of the best people get involved in it. Some of the greatest discoveries are made during this period.

Then, for whatever reason it turns over, the first people to leave a group are quite frequently those who are highly marketable and go somewhere else. And, by the time you isolate through a program several times, what you have caused is a diffusion out of some of the best and the retention of less than. So, it does tend to degrade the quality.

The other part is, I don't know how they know this, but undergraduate students and graduate students with some uncanny ability to see the future gravitate toward those fields for whatever reason there is—some continuity, stability and predictability. They want to get into an area where they can devote their lives to a particular field of science and believe that they have a chance to make effective progress over a long period of time. Failing to have that detracts from our ability to persuade our young people to consider careers in science and engineering.

Dr. MONCTON. I will make two points. The first is that the Advanced Photon Source benefited from a continuity in funding that has been extremely unusual in recent times. Maybe it's the only project of that size that received within a few percent of the targeted—the planned budget levels each year over the entire construction period starting in 1989.

So, I would urge that as a model for future projects. It certainly speaks to the need for the kind of stability that my colleagues are speaking about.

And, I can tell you what a pleasure it was to be able to direct a project of that magnitude with the stable budgets that we had. It enables you to use the money efficiently, because you can plan to use it and you have the people there to use it when the money comes.

Otherwise, you may have hired the people but have a short fall which makes it impossible for them to do the work. So, there are a number of insidious consequences of this roller coaster that Dr. Trivelpiece was talking about.

Let me just say from my personal experience, I was trained in neutron scattering. I did my Ph.D thesis with a 1994 Nobel Laureate in Physics, Dr. Clifford Shull at MIT.

And, I got into the neutron business just after this country had had a major investment in new facilities through the 60s and the early 70s. And, it was clear to me when that era had ended that there was going to be a very different future in neutron scattering from what it was immediately after the war when those big investments were made.

And, myself and many other young people, having just got their Ph.D's, migrated into other fields. That may be good or not for each of us. In my own case, I'm very pleased with what I'm doing now.

But, in many cases, people went away from that field. And, the field is under-optimized, let's put it that way, in the country today. And, we very much need a revitalization in the field of neutron scattering.

Chairman ROHRABACHER. Thank you very much. I think what we are talking about is honest budgeting, basically being honest with each other and trying to say this is what we are going to have to do in order to have a vibrant economy as well as a healthy scientific component to our society. And, this is what it's going to look like rather than trying to make promises that we can't keep or telling people that we are going to come back and revisit figures lateron rather than making tough decisions right up front and doing our very best job.

With that, Mr. Wamp, now we have a series of votes coming up. And, we have 11 minutes.

Mr. Wamp, would it be better for us to go on a break and then come back to ask the questions?

Mr. WAMP. Yes, sir, Mr. Chairman. I will need my full five minutes.

Chairman ROHRABACHER. All right. Well, why don't we break now and we will come back—how many votes are we having?

Mr. WAMP. Two.

Chairman ROHRABACHER. At least two votes. Okay. So, right after the final vote, if it's two or three, whatever it is, immediately after it begins we should come back and begin the hearing again.

So, I would say we will be in recess—let's say until—let's say a half an hour recess.

Mr. WAMP. Good.

Chairman ROHRABACHER. Okay. This Committee is in recess until 1:15.

[Whereupon, a recess is taken at 12:42 p.m., to reconvene at 1:33 p.m., this same date.]

AFTER RECESS

Chairman ROHRABACHER. And, we will now turn to Mr. Zach Wamp for his period of questioning.

Mr. WAMP. Thank you, Mr. Chairman. I'm sorry I wasn't here earlier to introduce Dr. Trivelpiece, who is from my home district.

I was in another part of the building asking another Tennessean questions before another committee and couldn't be here for your opening testimony. But, I have read that.

And, I want to associate myself with your comments, Dr. Trivelpiece, on treating the Office of Energy Research more like the National Science Foundation and maybe a little less like the Department of Housing and Urban Development, if you want to compare and contrast a little here. And, in my humble but sometimes accurate opinion, I think that Dr. Trivelpiece is the finest lab director in the nation and he's probably——

[Laughter.]

Mr. WAMP. (continuing) —got as much experience in this room as anybody in this room, based on my knowledge.

But, three quick questions for you, Dr. Trivelpiece, and then others could certainly answer. Our national laboratories, as we all know, benefit the regions that they are in in ways that we sometimes don't measure and sometimes are taking for granted.

In what ways do our national laboratories that are stretched, our multi-purpose labs and defense labs, all across the country, how can they benefit the region besides just inside the fence? How do they benefit the folks outside the fence?

Dr. TRIVELPIECE. The first is a very simple one. And, that has to do with the income that it provides to a region.

Certainly, in—I can't speak for the details in the other laboratories, but I'm sure the experience is similar. The Oak Ridge National Laboratory contributes something like $8 million a year to the tax base of the State of Tennessee.

There also are many jobs in the State of Tennessee. The people who are employed there, the retirees that are there. So, it's kind of the routine sorts of things.

There are activities that then involve the university, that we are—we provide about $23 million of support for the University of Tennessee at Knoxville as a result of work that is done collaboratively with them. Things continue in the education area, that there is a collection of graduate students that owe their degrees to studies they did in the areas of biology and biological sciences at the University.

We have 30 or 40 members of our staff who are on the faculty there. And, likewise, members of the faculty at the University come over there.

Certainly, in east Tennessee, it has caused new companies to come into being. And, one of the easy examples is the ceramics and the ceramics work at the high temperature materials lab.

That then led to a CRADA with Coors Brewing Company, Coors Ceramics. That led to a $3 million CRADA.

They since have put a manufacturing plant in Oak Ridge to take advantage of the scientific staff and knowledge that is there in the Oak Ridge. It goes on and on.

And, the ability to participate now at the state level with the Science Technology Council—and, as you know, Mr. Hollingsworth has been appointed by the Governor to have an economic development program. That economic development program recognizes science and technology as one of the key elements of the economic growth of the State of Tennessee and that the Oak Ridge National Laboratory is one of the key ingredients in the State's overall plan for economic development involving science and technology.

The activities that you had at the summit in Oak Ridge last year, I think that called attention to a lot of the benefits. You are having a summit in Chattanooga, which all of us are looking forward to to go down and participate in.

I think that institutions like national laboratories have ripples that carry out way beyond their immediate geographic boundaries. And, we obviously have close connections with individuals in nearby states.

I could go on for a long time, but in the interest of time——

Mr. WAMP. Do you see institutions of higher education being more and more linked to our national laboratories?

Clearly, the University of Tennessee and the Oak Ridge National Laboratory are one in the same in many respects now. And, I just wonder, because that seems to me to be a stabilizing effect for our students and for the laboratory systems as we try to define the mission of the national laboratories in the post-Cold War era. To me, they become linked at that higher education level on the advancement of all of our technologies and particularly basic research.

Dr. TRIVELPIECE. You have stated it very well. Yes, we do have close ties with the local universities.

We have less strong ties with the universities that are more geographically remote obviously. But, they are very strong.

We have 24,000 K through 12 students who come to the laboratory each year. If only 1 percent of them gets some inspiration to consider a career in science and engineering, it has been well worth the investment.

A good chunk of that is done by volunteers at the laboratory and not as part of funded programs, because we have an interest in seeing to it that people do get experience and contact with working scientists. Again, I could talk for a long time on this subject.

But, I believe the national laboratories in each of the regions in which they reside play a very important role in the economic well being of that region. But, it extends way beyond the regions in which they are located.

Mr. WAMP. Mr. Chairman, one more quick question, please. I heard the beep.

Chairman ROHRABACHER. Yes.

Mr. WAMP. I had a conversation a few minutes ago this morning with Dr. Krebs about neutrons and neutron science. Obviously, that's our expertise in the Oak Ridge area.

Can you just briefly tell us why neutrons are as important to our society and medical breakthroughs, et cetera, as they are?

Dr. TRIVELPIECE. An ability to understand and measure the properties and material is very important to us in terms of improving them, trying to find out what they do and so on. And, the discoveries that—the technique that Mr. Shull, Clifford Shull, who received a Nobel Prize for this, he advanced that.

Eight additional Nobel Prizes were received based on the simple idea that he had of passing neutrons through material and seeing where they come out, knowing where they went in and understanding where the atoms are. Probably the simplest technical example that I could give has to do with a relatively new idea.

If you weld a piece of material, you run heat along it, where the material has been welded, it's under stress. And, if you make it too cold, it sometimes breaks.

You would like to have material that you could weld together in such a way that it is light weight. For instance, the tanks that carry the shuttle into orbit, the more weight you put into them the less payload that you can have and the more fuel that you can carry.

If you make the material too thin and the tanks rupture, that would be a catastrophe. If you make them too heavy, a much bigger safety factor than is needed, then you are wasting money.

If you could get it right, it would be important. Well, the problem is nobody has a good way of measuring the stresses and strains inside material in their welds.

But, if you pass neutrons through them, you can tell where all the atoms are. So, you can find out where the atoms are in the material that wasn't disrupted by the welding process into where the material is disrupted by the welding process.

Each little pair of atoms, in a sense, constitutes a strain gauge. And, so by measuring their displacement from their normal location, you can measure the strains inside the materials.

That, alone, has been valuable in trying to understand how to make better welds, how to make gears that are in the automobiles, the ability to have those not fail and is critically dependent on understanding where the strains are. And, using neutron scattering as a technique to do that has paid many, many times over a great deal of the investment that was originally put in that.

And, yes, we think we are one of the centers of that science. And, yes, we do hope to have the upgrade for the facility that Dr. Krebs mentioned. And, we do believe that will contribute greatly to our ability to work in this area.[1]

Mr. WAMP. Thank you, Mr. Chairman.

Chairman ROHRABACHER. Let's see. I guess Mr. Fawell isn't here. So, Mr. Hastings.

Mr. HASTINGS. Thank you, Mr. Chairman. Once again, I want to thank you for the courtesy of allowing me to sit on this panel with you, even though I don't belong to the Commerce Committee.

But, I do—I have admired Mr. Madia since he has been in the Tri-Cities. And, I want to ask something to kind of clarify.

You, Dr. Madia, kind of glossed over this in your remarks a bit. The Chairman, I think, asked a very legitimate question that we are all wrestling with in this Congress. And, the essence of it is, how do we prioritize between different needs to expend research dollars, which I think is a very valid question and needs to be pursued.

The part that you glossed over in relationship to the 177 underground tanks that frankly need to be cleaned up, at least I won't say glossed over but maybe an application of those. In my introduction of you, I said that the times are changing at all these nuclear sites because the Department has started going to performance based contracts.

At our site, as you know, this new contract will go that way. Last week, in the National Security Committee, we passed to statutize performance-based contracts. I think that is the proper way to go, where somebody isn't paid unless they have something at the end, the product at the end that should be compensated for.

How does this concept, then, with EMSL coming into being, with the fact that we are changing the atmosphere on how we are going to clean up these sites—the figure that you are talking about is a figure that is accepted of $20 billion to $40 billion to clean this up. With this tied together with the Chairman's concern and, frankly, this Congress' concern, do you believe that with the idea of performance-based contracts that there can be some efficiencies made in the technology transfer with how you work together with the private sector and all these initiatives?

And, if so, can that be used in other areas of the world where they have similar problems?

Dr. MADIA. The quick answer is yes. When you are in the basic research business—and it is a business. You make investments. You expect returns.

You can put metrics around that business like any other business. Often, you are dealing with the precursors of success.

For example, one of the precursors we look at are the number of awards we get, independent awards, for our science and technology. That doesn't mean you have solved anyone's problems or cleaned up a tank, but you have, in fact, been recognized for a unique technology.

Later on, in the maturation of that science and technology, what you see is successful demonstration of that concept. Often, early on, it's a principle. It's a proof of concept.

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[1] See Appendix for an expanded answer by Dr. Alvin Trivelpiece.

As you mature the technology, you will do a successful demonstration. And, you will define an operating envelope for that technology.

Ultimately, you are going to deploy that technology. And, the real measure of success longer term is. Has that invention shown up in someone else's tool kit and is now at Hanford out there in the field actually doing the job, replacing what used to be the best technology with the new technology?

But, you have to take somewhat of a life cycle perspective on the development of that technology and look for precursors all along the chain.

The second point, which deals with the Chairman's question, in terms of priority, I have a strong bias for risk based prioritization of these programs. As you well know, at the laboratory we were the ones that first identify the fact that the spent fuel on the Columbia was the highest risk activity.

The political process that had set the agenda prior to that, unfortunately, had completely missed the fact that spent fuel was the highest risk activity at Hanford. And, so by taking a risk-based approach, you do begin to get a better handle on whether or not you should invest in this initiative or that initiative.

And, with all due respect, that's why I commented to the Chairman earlier that when I look at waste tanks at Hanford and the potential on global change, the risk there is so high in both cases they pass my screen. They were on the A-list in both cases.

But, you have to look at the entire budget and, in my opinion, make a risk based prioritization. And, that's now double in many respects.

Mr. HASTINGS. Just for your information, Mr. Chairman, if I may, what Dr. Madia is talking about is we had some spent fuel that was on the Columbia River. It was supposed to have been there for 20 days and it was there for 20 years.

And, to move it, there were three steps to go through. They eliminated essentially one step which had a savings, using this technology, of some $20 million or $30 million.

So, anyway, again, Mr. Chairman, thank you for your courtesy. And, thank you, Dr. Madia.

Chairman ROHRABACHER. I appreciate you waiting after lunch for us. And, I appreciate your testimony. I appreciate the testimony of the first panel.

Mr. Bartlett, do you have any other questions that you would like to ask?

Mr. BARTLETT. I'm sorry that I could not have been here for the testimony, because I'm very much interested in our labs and how we are going to use this very important national resource in the future. I don't know how many questions and how much of the dialogue has been involved with how do we determine where we go from here so that we can use, to the best advantage of our country, the enormous potential that we have in our national labs.

And, I think that this is a question that we need to resolve somehow so that our folks across the country and those of us who represent them here in the Congress are satisfied that this great national resource is used in the best way possible to secure for us the kind of future that we want. And, I'm wondering if you have recommendations as to how we might arrive at this consensus.

Clearly, the world situation and our national situation has changed since the laboratories were put into existence. And, as a result of that change, we need to refocus the use that we make of this great potential.

I am wondering if you have thoughts as to the best process to accomplish this so that everybody thinks that they had an input into the dialogue and so that all the parties involved can support the conclusion that's reached. Do you have some observations?

Dr. SHANK. You raised the question this morning about energy, the question asked on energy policy. I think a very important thing that we, as national laboratories, as part of the Department of Energy should be asking are, are we providing the information to you, the policymakers, about what the options for energy are?

Have we explored the whole universe? If we look at the question of fossil fuel versus nuclear fuel or fusion or renewable energy or any of the other elements, have we provided the scientific basis for that?

I think that our laboratories are used best when they respond to national questions. And, I think if we serve a national purpose we will need a basic research underpinning that will allow us to respond to those questions.

And, I think that using us in a way in which we provide information that will help the country and help the country plan its future, I think will be the most effective way to use our labs.

Mr. BARTLETT. Well, thank you. You gathered from my comments this morning I have a concern about our energy future, fossil fuels.

And, I know this is not a particularly politically popular thing to talk about here. But, fossil fuels are clearly not forever.

And, the process that produced them is not occurring at a rate anywhere near sufficient to replenish them. So, a time will come, sooner or later, depending upon what your view is as to the amount of fossil fuels yet remaining, but a time will come when we will not be able to depend as we have now on fossil fuels.

And, of course, one of the other big problems is that we have an enormous petrochemical industry that is based on these fossil fuels. And, if we use them all for energy, to what base do we turn for the kind of industry that now is so important in our society?

I agree with you that we have an urgent need to address nationally an energy policy that looks to our future and the world's future to see where we turn when oil no longer flows through the Alaska pipeline. And, that's going to happen in the not too far distant future.

We have now pumped about three-fourths of all the oil in Prudhoe Bay. If we go into ANWR, we will get another scant three billion barrels of oil.

And, in what, another half dozen or eight years or so oil will stop flowing through that pipeline. And, a fourth of all of our domestic production now goes through that pipeline.

So, we really have a big question about the future that we need to talk about.

Dr. Madia.

Dr. MADIA. Dr. Bartlett, two points. The first was mentioned earlier, but I would like to reinforce it.

Treating the Energy Research budget on a par with that of the National Science Foundation, as well as the NIH Laboratories, I think is essential. If we don't maintain that parity, we will systematically erode the capability you have invested in.

The second point deals with congressional jurisdiction. And, that is, we are called national laboratories but, in fact, we don't operate as national laboratories.

The Department of Transportation, the Department of Commerce all have basic research needs. But, because of jurisdictional issues, we don't actually function as your national laboratories.

And, having Congress deal effectively with that cross committee issue I think would maximize the productivity we have.

Dr. TRIVELPIECE. Obviously, one of the things that we can do is try to be honest brokers and provide facts. What are the irreducible collection of questions that need to be answered?

You mentioned the lack or the running out of oil in Alaska. Well, the possibility is, of course, drilling, deep drilling, out in the Gulf of Mexico.

You say, "Well, okay, we will just go get the people and make Texas Towers." Not so easy. There is a whole materials question that is associated with how you would make a tower that is deep enough to go out in the middle of the Gulf, how you would drill out there, what is the mechanical engineering.

There is a lot of work to be done. And, yet there is, of course, an enormous supply of gas and oil that is out in the deep water in the Gulf.

Can we develop the technology necessary? Well, somebody has got to start doing that. And, institutions such as national labs together with some of the industry would be an appropriate place to begin exploring what are the capabilities that are going to be required in order to explore and recover from deep water in the Gulf a supply of oil.

Dr. MONCTON. You have heard a couple of comments on the subject of risk assessment and prioritizing on the basis of assessing risk. Scientists think they are objective at doing that. And, maybe we are, at least more so than lay people.

But, the point I wanted to make is that risk assessment and the—risk and the perception of risk are two different things. And, the public at large perceives risks often quite differently than are actually represented by the risks. And, I think we all know that.

Risks are probably higher associated with fossil fuel than they are from nuclear power. But, the public doesn't perceive it that way.

Mr. BARTLETT. We have an education need here that we are not doing a very good job of fulfilling.

Dr. MONCTON. Right. We can provide information to help contrast the real risks with the perception of risk.

But, I think you folks sit in the middle between the scientific establishment on the one hand and the population on the other and feel the pressure from both sides. And, so I think it's important for us to help committees like this differentiate between real risk and perception of risk, because you will hear a lot from your constituents, from their side about the perception of risk.

And, a lot of the issues we are talking about this morning, I think, are impacted by that distinction.

Mr. BARTLETT. Thank you very much for your comments. Thank you, Mr. Chairman.

Chairman ROHRABACHER. Just to note that many of the comments today by this panel would reinforce Chairman Walker's contention that we need a Department of Science that would basically make sure that the laboratories are treated with the status that they should be treated rather than being treated as just part of—part and parcel of some other operation. So, I think that that's one thing that's really brought home in this congressman's mind after hearing your testimony today.

I appreciate it again. And, I don't have all the answers. And, as a matter of fact, sometimes I don't even have the questions.

But, I do know that we have to make the best decisions that we can and that sometimes no decision is the worst decision. And, all that may be a string of cliches, but it comes down to the point where we have to do our very best with what we've got.

And, I was given a task last year to make sure that we handle the amount of energy and environmental research that this country does in a way that in the end, after a long period of—after seven years we would have a balanced budget and still have a viable and vibrant scientific research community. And, the fact is that we've done our best in that, but there has been a lot of pains in doing this.

And, your recommendations—and you are helping with helping us make and set our priorities—is always welcome. It's especially welcome if you can tell us where money is being wasted.

And, I always say this to people. But, very rarely do I get back—I always get back where we should spend the money, but I never get back any suggestions where we shouldn't spend the money.

And, so—and that's very difficult, because I don't pretend to be a scientist. I mean, we are lucky to have Roscoe Bartlett here, who has got a Ph.D and is a scientist.

And, so with that——

Mr. BARTLETT. Excuse me, Mr. Chairman. You know, there is a Biblical statement that explains why you don't get back that response.

And, that is. This you ought to have done and not to have left the other undone.

Chairman ROHRABACHER. Say that again.

Mr. BARTLETT. This ought you to have done and not left the other undone. In other words, there is nothing that is being done that can't be reasonably defended.

Chairman ROHRABACHER. Got it. That's right.

[Laughter.]

Mr. BARTLETT. Or they wouldn't be doing it.

Chairman ROHRABACHER. Well, I can see you are a scholar on more than your scientific scholarship. You are a Biblical scholar as well.

And, some people say I need to study the Bible, as well. But, with that, I want to thank all of you.

And, we are going to do our best. We are going to work together here.

And, we are people of good will. And, we all love America. And, we all are concerned about our fellow human beings.

And, we know that science plays such an important role in whether or not the human condition is something that is fine and something that people can live and have enjoyable lives or whether it's going to be miserable and whether people will be plagued with all kinds of toxic challenges and diseases that they get from these toxic problems and such. So, I believe that with freedom and with technology, there is just about—I mean, we can overcome any challenge.

We can overcome any problem. And, you folks, as long as we make sure that you are not diverted away into things that are not necessarily areas that—for example, as long you don't divert money that should be going to you for research into commercialization projects or subsidies or somebody's business operation, maybe you will come up with some of those answers.

And, in a free society, if you provide the answers, some people are going to see those answers and are going to say, "Look, I can take those answers and solve some problems and maybe make some money doing it."

So, with that, thank you very much. This Committee is adjourned.

[Whereupon, the hearing is adjourned at 1:58 p.m., Wednesday, May 8, 1996.]

[The following material was received for the record:]

OAK RIDGE NATIONAL LABORATORY
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May 24, 1996

The Honorable Dana Rohrabacher
Chairman, Subcommittee on Energy
and Environment Science Subcommittee
2320 Rayburn House Office Building
Washington, D. C. 20515-6301

Dear Mr. Rohrabacher:

It was a pleasure to testify before the Committee on Science, Subcommittee on Energy and Environment on May 8, 1996.

Enclosed please find corrections and a letter requesting my expanded answer be included to a question about the importance of neutrons in our national research agenda beginning on page 126.

Thank you for this opportunity.

Sincerely,

Alvin W. Trivelpiece

Enclosure

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July 9, 1996

The Honorable Dana Rohrabacher
Chairman, Energy and Environment Subcommittee
Committee on Science
U.S. House of Representatives
Rayburn House Office Building Suite 2320
Washington, D.C. 20515-6301

Dear Mr. Rohrabacher:

Enclosed are my responses to additional questions concerning my testimony on May 8, 1996, before the Energy and Environment Subcommittee of the House Committee on Science.

In this hearing, I responded to a question about the importance of neutrons in our national research agenda. I would appreciate the privilege of extending my response for the hearing record.

The influence of neutron science spans across virtually every facet of our society from the very practical to the very basic. The early uses of neutron science occurred with the production of nuclear material for the atomic bomb which changed history for all time. Almost immediately after this stark realization, it became clear that neutrons would become one of the most practical and useful tools of mankind.

Shortly after the experiment under the football stadium at the University of Chicago, which demonstrated that a graphite pile could be configured to promote a self-sustaining chain reaction in uranium, the graphite reactor at Oak Ridge National Laboratory (ORNL) was constructed and became the first working research reactor. It pioneered the plutonium separations process that was used at Hanford to produce plutonium for the atomic bomb. ORNL also achieved many other "firsts" that were to mark the way for the future of neutron science. The first radioactive isotopes were produced at the graphite reactor and shipped to a St. Louis hospital where they were used for medical diagnosis; the first demonstration that nuclear energy could be used to generate electricity was performed; and Clifford Shull and Ernie Wollan demonstrated that neutron beams from the reactor could be used to understand the atomic structure of materials. This latter pioneering work in the late 1940s laid the foundation of what is now neutron scattering, and it earned Cliff Shull a share of the 1994 Nobel Prize in Physics. As I mentioned in my testimony, there have been eight Nobel Prizes that have benefited from neutron science since that early work.

To provide a better feel for uses of neutron science today, and why we so desperately need a new, more powerful source of neutrons to regain our competitive position with the rest of the world, I have provided a few examples below.

Just as beams of light can be used in a microscope to reveal much smaller objects than we can see with the unaided eye, so beams of neutrons can be directed onto solids to allow scientists to "see" how the atoms that make up the solid behave. Even though neutron beams are primarily considered a "research tool," they make unmistakable contributions to the everyday lives of people. This is best understood by considering some specific properties of neutron beams and how they contribute to science and technology.

- Neutrons are used to test materials that will be used in fission and fusion reactors needed for future energy production. The entire commercial power industry has been successfully built on materials specifically developed for use in research reactors, and the understandings that resulted have led to many useful alloys now used throughout U.S. industry.

- Since neutrons have no charge, neutrons interact weakly with most materials and can thus penetrate to great depths–unlike x-rays that stop at the surface. This is especially important for controlled environmental experiments (such as observing lubricant flow in an operating engine or biological molecules immersed in water). This technique is also routinely used to inspect our nuclear arsenal.

- Those few neutrons that do scatter from the nuclei of atoms inside materials give us unique information about how the scattering atoms are arranged to make up the solid, the dynamic behavior of the atoms, their vibrational energies, and much more. This allows scientists to actually "engineer" new materials tailored to specific applications (e.g., new plastics).

- Neutrons have no systematic dependence on the atomic number (of protons) of materials. Neutrons are particularly sensitive to lightweight materials like hydrogen, oxygen, etc. This makes them a complementary probe to x-rays (which scatter best from heavy materials), and makes them particularly useful for studying biological molecules, plastics, ceramics, complex fluids, aerospace materials, etc.

- Neutrons behave like little magnets. Virtually all of our knowledge of magnetic materials, such as those used in computer storage discs, credit cards, and automobiles, have come from neutron science and will continue to do so.

- Absorbed neutrons can transmute atoms to create unique isotopes used for medical diagnosis and treatment, industrial applications (such as gauging the thickness of rolled sheet-steel), and military applications.

- Absorbed neutrons can also make atoms radioactive and cause them to emit radiation that uniquely identifies them. This process, called neutron activation analysis, has been used for such applications as identifying pollutants in the environment and proving that President Zachary Taylor was not poisoned with arsenic.

- Neutrons are used extensively for fundamental investigations in the field of physics, chemistry, materials science and engineering, biology, atomic and nuclear physics, astrophysics, and medical research.

In closing, I would like to reiterate that it is important for the U.S. to proceed with timely construction of a new neutron source. As you know, the Department of Energy (DOE) is almost uniquely responsible for constructing and operating both accelerator-based spallation and reactor neutron sources for the entire scientific community because of their complexity. Although DOE has been seeking new neutron sources since the 1970s, other major facilities construction and budget constraints have precluded either a new source or upgrades to existing sources. Meanwhile, the rest of the world has advanced. For the past 15-20 yeares, the best neutron sources have been in Europe. The Japanese recently announced construction of a new spallation neutron source, and the European Community is completing a feasibility study for a new spallation source. Without a new source of neutrons for science and industry, the U.S. will lose its competitive advantage in a field it not only pioneered but one that has become indispensable to science and technology.

Sincerely,

Alvin W. Trivelpiece

AWT:mah

Enclosure

File-RC

Energy Policy

The Department's energy policy supports the development of technologies that advance energy security and improve environmental quality. These technologies are meeting the concerns of the American public for a sustainable energy future. The clean energy technologies emerging from DOE research are increasing the nation's economic productivity and lowering America's energy bills, while decreasing the environmental impacts of energy production and use.

The Department also advances the use of U.S. clean energy technologies both domestically and worldwide. The federal role in energy research and development is justified by energy and environmental trends that will affect the nation in the long run. The private sector tends to under invest in the long-term research required to develop the energy technologies that will meet the nation's long-term national security and environmental needs. This is why the Department leverages federal funding with non-federal resources to develop technologies for a cleaner and affordable energy future.

Large Hadron Collider

At congressional hearings on the FY 1996 budget, I stated that discussions with CERN regarding U.S. involvement in the Large Hadron Collider were in the very early stages, and that no agreement had been reached on the extent or the specifics of any collaborative effort. Based on the current status of our formal negotiations with CERN, we now expect that an agreement can be finalized by the end of calendar year 1996.

Galvin Report Recommendations: DOE Position, Commitments, and Deadlines
National Security

Recommendation	DOE Position	Action
1 The primary mission of the weapons laboratories must be safe, secure and reliable nuclear stockpile in the absence of explosive testing Science-based stockpile stewardship requires the following rank-order priorities - Attracting and retaining skilled scientists. - Enhancing surveillance of weapons - Continuing hydrodynamic testing - Assessing problems, reanalyzing previous data - Sustaining the scientific process	Support	**Commitment**: The Department has taken major steps in response to these two recommendations In July 1995, the Department issued a Charter for a permanent R&D Council whose purpose is to coordinate and integrate R&D across the Department, thereby improving the linkage between basic and applied research and technology development, and to facilitate more effective planning, budgeting, management, and evaluation of DOE R&D programs The Council members are the Assistant Secretaries and Directors of the major mission areas of the Department and the senior career deputies from these organizations In addition in August 1995, the Department announced the creation of a permanent Energy Resources Board to oversee the Department's energy policy and energy research and development portfolio. The Board focuses on 1)integration of policy, program planning, budgeting and implementation, 2) strengthening customer access and service delivery, 3) improved operation efficiency and cost-savings, and 4) improved coordination of basic and applied energy research programs The Board members are the Assistant Secretaries and Directors of energy organizations and the Office of Policy The Board uses a baseline guidance the July 1995, National Energy Policy Plan, "The Sustainable Energy Strategy" - Clean and Secure Energy for a Competitive Economy Integration of energy and environmental considerations is fundamental to a Sustainable Energy Strategy The Council and the Board have been active in carrying out its mandate **Deadline:**
2 Non-proliferation, counter-proliferation verification, and intelligence support have become a major mission along with stewardship of the nuclear stockpile Organizational compartmentalization within the Department complicates and makes difficult the appropriate inter-relationship and funding balance the Department's organization reflect their importance and interdependence funding balance the Department's organization reflect their importance and interdependence	TBD	**Commitment:** Recommendation suggests that Office of Defense Programs and Office of Nonproliferation and National Security either be merged or that programmatic activities receive greater integration. These options are being examined in the Strategic Alignment **Deadline:**

3. Lawrence Livermore Laboratory should retain enough nuclear weapons design competence and technology base to continue its activities in non-proliferation, counter-proliferation, verification, and intelligence support, to provide independent review for several years while alternative approaches to peer review are developed, and to participate in weapons relevant experiments on the National Ignition Facility (NIF). Lawrence Livermore National Laboratory would transfer as cost-efficiency allows over the next five years its activities in nuclear materials development and production to the other design laboratory. Lawrence Livermore National Laboratory would transfer direct stockpile support to the other weapons laboratories as the requirements of science-based stockpile stewardship, support of the DoD nuclear posture, and the status of the test bans allow.	Support, with qualifications	**Commitment:** The Department supports the study of a careful phase-down of some of Lawrence Livermore's nuclear weapons work, combined with a reemphasis on non-proliferation, counter-proliferation, and verification activities. Timing and details of phase-down will depend on assessment of how best to meet continuing national defense requirements in absence of testing. Alternative methods of retaining peer review will be examined to provide basis for any decisions. **Deadline:**
4. Continued funding support for the Dual-Axis Radiographic Hydrodynamic Testing (DARHT) facility, continued near-term support for the Los Alamos Neutron Scattering Experiment/Los Alamos Meson Physics Facility (LANSCE/LAMPF); continued pursuit of advanced computing, including computing through workstation networks, and proceeding with the National Ignition Facility (NIF) as a research facility, balanced with respect to other major investments.	Support	**Commitment:** The Department will provide continued support for each of these elements of the science-based stockpile stewardship program. President's FY 1996 budget includes $32 million for DARHT, $25 million for LANSCE, $45 million for advanced strategic computing, an $61 million for design activities associated with the National Ignition Facility. **Deadline:**
5. Future production needs should be based on residual capabilities of Pantex, Los Alamos National Laboratory, and Sandia National Laboratories, and believes that no further investments in production capability are needed at this time.	Oppose	**Commitment:** The Department is committed to ensuring the safety, security, and reliability of the existing U.S. stockpile well into the future, which will require a smaller, more cost-effective production complex to replace the stockpile when needed, including limited life components and a new tritium source. The President's FY 1996 budget includes $50 million to support a new tritium source. Existing production capabilities will be downsized, but production capabilities within the weapons laboratories may be required. **Deadline:**

Energy and Environment

Recommendation	DOE Position	Action
1 The Department should organize itself to achieve greater integration among its applied energy programs, between these programs and industry, and between the applied energy and basic energy research work performed at the laboratories	Support	**Commitment:** The Department establishes in October 1994 the Task Force on Strategic Energy R&D, chaired by Daniel Yergin, in part to develop a plan that would assist in meeting the goals established by this recommendation **Deadline:**
2 The integration of energy and environmental considerations should be q fundamental organizing principle for much of the Department's activities	Support	**Commitment:** The Department is committed to sustaining and building on its partnerships with major energy-and materials-intensive industries, and to use these partnerships as an expanded framework for meeting the Task Force recommendation. Specifically, the Department has developed ons working on technology roadmaps for the forest products, refining, steel, glass, chemical, metal casting, and aluminum industries--which collectively account for more than 80 percent of the nation's manufacturing energy use and together generate approximately 90 percent of U S manufacturing waste **Deadline:**

Lab Missions and Organization

Recommendation	DOE Position	Action
1. The Department and the national laboratories should move promptly to establish clear mission statements for the laboratories which will be utilized as tools for budget decisions and long-term strategic planning	Support	**Commitment:** The Department, working with the Laboratories, has drafted the Strategic Laboratory Mission Plan. This plan identifies the mission activities performed at each laboratory and the role of the laboratory as principal, contributing or specialized participant in fulfilling this mission these designators may be used in building on areas of excellence, enhancing clarity of focus for each lab, and identifying areas for streamlining. The Laboratory Operations Board, will provide advance on developing refined mission allocations to the labs
2. Mechanisms should be established to enhance the management of the multi-program laboratories as a system.	Support	**Commitment:** Considerable progress has been made in the National Laboratories as a system. DOE Laboratory Operations Board has examined the existing laboratory subsystems which have developed to fulfill missions and will continue to work with the laboratories to identify and implement means of further integrating National Labs into a system.
3. The Department should establish lead laboratories according to mission assignments and programmatic strengths.	Support	**Commitment:** Principal, contributing or specialized participating roles for the laboratories in the DOE mission areas have been identified in the Strategic Laboratory Missions Plan.
4. The Department should establish Centers of Excellence within the laboratory system.	Support	**Commitment:** Centers of Excellence will be established, as appropriate, in support of missions as identified in the Strategic Laboratory Mission Plan.

Recommendation	**DOE Position**	**Action**
1. Improvements in DOE management are needed.	Task Force Failed to learn current program status	**Commitment:** The Task Force seems to be unaware of the substantial progress the Department has already made in improving the management capabilities in the environmental management program at all levels The Task Force had minimal direct interaction with the program, and appears to have relied too heavily on outdated reports. The Department has significantly increased management capability by hiring and training competent project managers, cost estimators and contract coordinators. This new management capability has already resulted in a savings of more than $500 million in the Environmental Management program. Also, the Quality Improvement Team concept (QIT) has afforded the Department continuous improvement in its management enterprises. **Deadline:**
2. The EM program requires a substantial commitment and high priority addressing the challenges of this program.	Support completed	
3. Establish an Environmental Advisory Board EAB reporting to the Under Secretary.	Completed	**Commitment:** The Department already has established several advisory boards and independent reviews to service the Environmental Management program. Our challenge is not to create more advisory boards, but to use the ones that exist more effectively. We commit to continue utilization of: (1) an existing Environmental Managemental Advisory Board (EMAB), (2) two ongoing studies by panels of the National Academy of Sciences, (3) the Development of On-site Innovative Technologies (DOIT) Committees, and (4) Site Specific Advisory Boards that exist at every major cleanup site. The EMAB, of which the Task Force apparently was unaware, was established in 1990 to help guide policy. The Board has 28 members representing a wide range of organizational perspectives and fields of expertise, including the National Laboratories, EMAB subcommittees exist to address key issues, including risk management, cost-effective cleanup, and technology development and transfer.

4. The national laboratories should play a larger role than at present in...the Environmental Management program.	Support, with qualifications	**Commitment**: The Department will continue to provide strong support to the National Laboratories for environmental clean-up technology development. In FY 1995, DOE laboratories will receive $150 million (45%) of the Environmental Management program's $336 million technology development effort. Lead labs recently have been established for the major Environmental Management Technology Development Focus areas, as recommended in the Task Force report. Cost and performance of the DOE labs vis-a-vis other R&D performers will provide the basis for decisions regarding future funding allocations. Efforts to reduce the costs of business at the National Laboratories should enhance their competitive position for funding increases in this and other areas of R&D. **Deadline:**
5 The national laboratories should be available to the entire government system as a powerful environmental technology resource.	Support	**Commitment:** The Department strongly agrees with this recommendation and will continue to work with other Government agencies to help facilitate enhanced utilization of the Laboratories in areas where laboratories' technology capabilities might help provide cost-effective R&D solutions. The Department and/or DOE laboratories currently have Memorandums of Understanding with other Executive Branch entities including: the Department of Defense, Department of Health and Human Services, National Institute of Standards and Technology, Environmental Protection Agency, Department of Agriculture, and Department of Transportation. These agreements help provide the framework for making the National Laboratories available as a national resource. The Department will work aggressively with other agencies to match laboratory capabilities with national R&D needs. **Deadline:**

6 DOE must address more forcefully the task of renegotiating the unrealistic or unfeasible elements of the cleanup compliance agreements that it has made with State and Federal agencies	Support	**Commitment:** Budget realities are forcing the Department to continue its renegotiation of many existing compliance agreements, thus creating a more workable, affordable, and results-oriented compliance regime. Consideration progress' already has been made, including the 1993 renegotiation of the Hanford agreement at a savings of more than a billion dollars, and renegotiation of dozens of smaller agreement throughout the country. The Department is committed to making structural changes to our compliance agreements to provide the necessary flexibility because of shifting site conditions and budget realities. For example, we are seeking to replace elaborate long-term enforceable schedules with enforceable short-term schedules with greater emphasis on results-oriented milestones rather than process milestones. **Deadline:**
7 Much more comprehensive involvement by members of the affected public in decision making should be employed to reduce the bitterness, distrust and distress that continues to provide a troublesome element in DOE's conduct of affairs.	Support/Partially Completed	**Commitment:** The Department agrees that public and stakeholder involvement is vital, and has already taken a number of major actions to accomplish this goal. For example, in the Environmental Management program, the Assistant Secretary established the Office of Public Accountability. Other initiatives include the expansion of the Environmental Management Advisory Board, the formation of numerous Site Specific Advisory Boards (SSABSs) at many DOE sites, and a technology development program that incorporates public input. Since 1993, "Establishing a stronger partnership between the Department of Energy and its Stakeholders" has been one of the six strategic goals of the Environmental Management program. Independent surveys have demonstrated significant improvements in the public's trust and confidence in the Department. **Deadline:**

8. The bulk of EM environmental challenges, although presenting no immediate threats to public heath or safety, still should be addressed with a heightened sense of urgency.	Completed, within budget limits.	**Commitment:** Although the Department generally agrees with this statement, limited resources will ultimately determine the pace at which these risks can be addressed. Hence, the Environmental Management program's first strategic priority is to "Eliminate and manage the urgent risks in the system." This goal reflects the reality of limited resources available to the Environmental Management program. Some actions must be deferred where there is no near-term urgent risk, and to invest in new technologies that will reduce the cost and increase the effectiveness of a more sustainable remedy. This strategy recognizes the need to focus available funding on existing urgent risks and to identify emerging risks, while developing productive and cost-effective technologies for the long-term success of the program **Deadline:**

Recommendation	DOE Position	Action
1	Support has been provided	**Commitment:** The Department has taken two important actions to strengthen efforts in fundamental science at the labs and universities: 1) In high energy physics, DOE has responded to the Drell report to revitalize the program in the wake of the termination of the Superconducting Super Collider (SSC). Increased funding provided to university groups that were funded directly by either the Federal Government or the State of Texas through the SSC project. In addition, some initial funding was made available to allow both universities and the Department's high energy physics laboratories to explore possible areas of collaboration in the Large Hadron Collider to be built at CERN, and 2) The $100 million Science Facilities Initiative has provided a significant increase in output of basic science from the Department's scientific user facilities, benefitting several thousand researchers in universities, the national laboratories and industry. The Laboratory Operations Board monitors the Department's investments in fundamental research.
2 The DOE should pay close attention to ensuring that a proper balance is maintained between the universities and the national laboratories in the performance of DOE related basic research, both now and in the future	Support	**Commitment:** During the next year, the Department will request its science advisory committees to examine the balanced between university and laboratory research programs in those instances where this has not been done recently. **Deadline:** Review of all major categories of DOE science funding is contained in the Draft Strategic Laboratory Missions Plan, Vol II. The Department's commitment to this balance is contained in Volume I of the Plan

3.	Oppose	**Commitment:** The Department does not believe that the recommendation would provide significant benefits, and could greatly reduce management's flexibility to respond to unexpected needs in either research or facility operations funding. Research and facilities are not unrelated in the sense that a considerable amount of funded research depends on operation of facilities. For example, a facility could require extensive, unexpected repair, but would not have sufficient funds in a separate facilities account Without the ability to quickly move funds to fix such a problem, a considerable number of scientists and their research in universities and industry as well as the national laboratories could be adversely affected causing considerable losses in productivity. Conversely, there might be a need in a research program that could be best met by moving facilities operating funds to support the research
4. The DOE should redouble its efforts to achieve better integration of basic research, technology development programs, and their applications, particularly in the areas of environmental remediation	Support	**Commitment:** The Department is committed to fostering the timely transition of research results from fundamental discovery to functional application There already exists considerable interaction between the Department's basic and applied research programs. One of the most effective means of integration is through the collocation of basic and applied research. While there are many integration activities already underway, we agree with the Galvin report recommendation that improvement is necessary. There is an urgent need to better integrate research related to environmental management. In that regard, we will establish a Research and Development Council, reporting to the Under Secretary, to ensure high level support for integration of basic and applied research programs. This Council provides policy guidance for various integration activities, e.g., development of technology road maps for the applied programs that require advances in basic research. In addition, the Office of Energy Research and Office of Environmental Management have developed an integrated strategic plan for coordination for R&D Workshops involving the scientific community (including representatives from the labs) and environmental cleanup experts have facilitate development of this plan.

5. Basic research at the laboratories should be more fully integrated into the national and international research community Two day interpretation workshop with laboratory, university and DOE participants to discuss learned and best policies for improving integration Industry participated as panelists Now preparing recommendations to the Secretary on way to improve integration	Support	**Commitment:** The Department agrees with this recommendation However, implementation will vary from one field of research to another. Research in the fields of high energy physics, nuclear physics, fusion energy, human genome, and global climate change already are tightly integrated nationally and internationally Several interagency and international agreements ensure this integration The Department will undertake a broad examination of this issue using its advisory committees and will seek their recommendations to better integrate research activities not captured by existing frameworks between the labs and other R&D performers The Science Facilities Initiative will help foster additional interrelationships between the labs, industry, and academia.
6 There should be additional stimulation of laboratory-university cooperation in basic research	Support	**Commitment:** Existing laboratory-university relationships are very good in some areas, but not as strong as they might be in others These interactions are particularly strong at the scientific user facilities In addition, there exist many very strong cooperative research activities between the laboratories and universities. Intellectual renewal is facilitated through cooperation between the laboratories and universities. To enhance the level of interaction, the Department will, as a matter of policy, encourage and reward its laboratories for establishing cooperative research programs with universities and industry as partners in laboratory basic research In addition, we will implement improved means of achieving enhanced integration of the laboratories into the national R&D infrastructure. **Deadline:** Pilot projects in remote access of DOE user facilities during calendar 1996, beginning with the Advanced Photon Source.

Economic Role of the Labs

Recommendation	DOE Position	Action
1 The government-funded technology transfer/industrial competitiveness activities of the national laboratories should be focused on industries and areas of technology that contribute to the DOE's primary missions in national security, energy and environment	Support	**Commitment:** The recommendation will be fully implemented by the imminent issuance of criteria for partnership formation. The criteria, which have been in preparation for months, require all partnerships to 1) Support core missions, 2) provide economic and other benefits to the nation, 3) have clear measures to ensure performance and accountability, 4) be formed in a fair and open manner, and 5) be managed by best business practices **Deadline:**
2. Laboratory directors should have the flexibility to initiate or to approve new technical projects at the periphery of current laboratory activities.	Support	**Commitment:** The Department will examine and clarify guidance on the appropriate use of laboratory directed research and development. Laboratory directors currently discretionary funds that they may use to initiate new technical projects at the periphery of current missions. Laboratories are allowed by statute to use these for industrial partnerships. **Deadline:**
3. Competitive selection and more rigorous technical and merit review by external experts should be applied within the Department's CRADA activities	Support, with qualifications	**Commitment:** The Department will examine its existing CRADA review and selection process to seek opportunities to expand competitive selection and technical and merit review by external experts. The Department is committed to rigorous, criteria based, CRADA selection process. We believe that competitive selection and external peer review is appropriate selection and external peer review is appropriate for some but not all classes of CRADAs. For small CRADAs, for example, the benefits from external review may not be worth the cost and time to conduct the review. Similarly, when a potential partner comes to us with a propriety problem and proposes a cooperative research program that is in the Department's interest, it may not be appropriate to require competitive selection. **Deadline:**

Governance

Recommendation	DOE Position	Action
1. Over a period of two years, the Department and Congress should develop and implement a new modus operandi of Federal support for the national laboratories based on a private sector style - "corporatized" - laboratory system.	Opposes as delineated; support in modified form	**Commitment:** The Department supports development of a new modus operandi for the National Laboratories, but believes the goals established by the Galvin Report can be accomplished within the existing Government-Owned, Contractor-Operated model using best business pratices. The Department has reduced its intensive oversight of the laboratories thru the use of a laboratory self-assessment process augmented by annual two week reviews by DOE functional and ES&H line managers. DOE Orders and Directives have been reduced by more than 50%, the requirement that laboratory procurements follow the Federal norm has been eliminated; and, Work Smart Standards, which tailor safety requirements to the facility rather than entire site, have been piloted successfully.

QUESTION FROM REPRESENTATIVE ROHRABACHER

General

Q1. Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) shows the following budget outlay profile for the DOE General Science and Research programs (i.e., High Energy and Nuclear Physics): FY 1996 = $978 million; FY 1997 = $1.002 billion; FY 1998 = $948 million; FY 1999 = $865 million; FY 2000 = $781 million; FY 2001 = $840 million; and FY 2002 = $959 million.

a. Did DOE have any input into the development of these figures?

A1. No. We understand the outyear estimates for the Department of Energy General Science and Research programs were developed by the White House and represent mathematical calculations of the estimates supporting the President's deficit reduction plan. We understand these estimates do not represent policy decisions regarding the value of the basic research programs funded in this appropriation.

QUESTION FROM REPRESENTATIVE ROHRABACHER

General

Q1. Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) shows the following budget outlay profile for the DOE General Science and Research programs (i.e., High Energy and Nuclear Physics): FY 1996 = $978 million; FY 1997 = $1.002 billion; FY 1998 = $948 million; FY 1999 = $865 million; FY 2000 = $781 million; FY 2001 = $840 million; and FY 2002 = $959 million.

b. What are the implications of these outyear figures, which dip at low as $781 million in FY 2000, for both the domestic high energy and nuclear physics programs, and for the potential U.S. participation in the construction and operation of the Large Hadron Collider (LHC) at CERN?

A2. In the High Energy Physics program the suggested outyear projections would require major reductions (approximately 30% decrease by FY 2000) in both university and laboratory support. Termination of major portions of laboratory programs (eg. Next Linear Collider R&D at the Stanford Linear Accelerator Center, one of the collider detectors at Fermilab, Fermilab fixed target program) would be necessary and upgrades or new capabilities at the remaining accelerator facilities would be precluded. If the budgets decline as suggested by the outyear projections, it would be extremely difficult to participate in the Large Hadron Collider to any significant degree.

In the Nuclear Physics program these reduced budgets (approximately 30% by FY 2000) would have a major impact. They would cause significant redefinition of supported research programs, and result in the closure of world-class Nuclear Physics accelerator facilities. The Nuclear Science Advisory Committee (NSAC) would be consulted on scientific priorities before selection of facilities to be closed. Present guidance and scientific prioritization from NSAC is based on a funding profile provided by the Department of Energy and the National Science Foundation, and is inadequate to assist with a reduction of such magnitude.

QUESTION FROM REPRESENTATIVE ROHRABACHER

General

Q2: Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc 104-162/Vol. 3) also shows the following budget outlay profile for the DOE Energy Supply R&D programs: FY 1996 = $3.907 billion; FY 1997 = $3.587 billion; FY 1998 = $3.504 billion; FY 1999 = $3.385 billion; FY 2000 = $3.214 billion; FY 2001 = $3.098 billion; and FY 2002 = $3.283 billion.

a. Did DOE have any input into the development of these figures?

No. We understand the outyear estimates for the DOE Energy Supply R&D programs were developed by the White House. The estimates are only the R&D portion of the 271 function in the President's Request. We understand these estimates represent mathematical calculations of the estimates supporting the President's deficit reduction plan. We understand that some policy decisions are represented by these estimates which provide increases for selected non Energy Research programs in the Energy Supply Research and Development Appropriation, e.g., solar and renewables.

QUESTION FROM REPRESENTATIVE ROHRABACHER

General

Q2. Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) also shows the following budget outlay profile for the DOE Energy Supply R&D programs: FY 1996 = $3.907 billion; FY 1997 = $3.587 billion; FY 1998 = $3.504 billion; FY 1999 = $3.385 billion; FY 2000 = $3.214 billion; FY 2001 = $3.098 billion; and FY 2002 = $3.283 billion.

b. What are the implications of these outyear figures, which dip at low as $3,098 billion in FY 2000, for OER programs--such as Basic Energy Sciences--in this account?

A2. These outyear projections would result in significant program reductions. For the Biological and Environmental Research program, for example health effects research addressing impacts of energy production and use would be reduced as would important research in the human genome and structural biology programs. Research in bioremediation needed to develop more economical and efficient cleanup of contaminated sites would be reduced, the operation of the Environmental Molecular Sciences Laboratory would be reduced and the global environmental change program would be reduced.

For the Basic Energy Sciences program, research on a national spallation neutron source would be terminated. Several major scientific user facilities would have to be identified for shut down and there would be significant reductions at colleges, universities and at the national laboratories.

For the Fusion Energy Sciences program, the outyear estimates would make it difficult to implement the recent recommendations of the Fusion Energy Advisory committee and unique opportunities for new science could be lost.

QUESTION FROM REPRESENTATIVE ROHRABACHER

General

Q3. What specific changes are proposed in the FY 1997 OER budget request that reflect recommendations contained in the report of the Task Force on Alternative Futures for the Department of Energy Laboratories (i.e., the Galvin report)?

A3. Due to the Department's initiatives and laboratory efforts to control costs, particularly in the administrative areas, the Office of Energy Research FY 1997 budget request was smaller than it would have been. The Office of Energy Research will be able to continue its program missions in an environmentally safe manner and provide necessary oversight with fewer dollars. Specifically, the Fiscal Year 1997 budget for the Office of Energy Research shows strong support for basic research and engineering programs as recommended by the Galvin Task Force. The Department redirected the fusion energy program into a strong fundamental fusion science program, and provided less support for the technology transfer program.

QUESTION FROM REPRESENTATIVE ROHRABACHER

General

Q4. The Administration's proposed Section 621 of the government-side General Provisions in the *Appendix* volume of the *Fiscal Year 1997 Budget of the United States Government* (see H. Doc. 104-162/Vol. 2, page 12), includes $13.0 million for the Combustion Research Facility, Phase II, at Sandia National Laboratories-Livermore; $35.2 million for the B-Factory at Stanford Linear Accelerator Center (SLAC); $36.75 million for the Fermilab Main Injector; and $131.216 million for the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. These amounts are not included in DOE's budget request, and these provisions are under the jurisdiction of the Appropriations Subcommittee Treasury, Postal Service, and General Government, which does have jurisdiction over DOE programs.

What is the purpose of these funds, and why are they requested in government-wide General Provisions, rather than from the Appropriations Subcommittee on Energy and Water Development?

A4. As part of an on-going effort to improve planning and budgeting for the acquisition of fixed assets, including major construction projects, the President's budget includes an allowance for the additional budget authority required to fully-fund certain projects, including those detailed here, for FY 1998 through the projects' completion. Good budgeting requires that the full costs for asset acquisition be provided up-front to help ensure that all costs and benefits are fully taken into account when decisions are made about providing resources. In most cases, this practice has been followed throughout the government. For historical reasons, the Department of Energy (and other agencies) has incrementally funded fixed asset acquisitions, without certainty when or if future funding will be available. This can, and occasionally does, result in acquisition of assets not yet justified, higher acquisition costs, cancellation of major projects and the loss of sunk costs, and/or inadequate funding to maintain and operate the assets.

For the projects identified here, the FY 1997 incremental budget authority for each of these projects is requested as an appropriation to the Department of Energy account The additional amounts required for full-funding are requested in a Government-wide general provision, a method proposed only for this transition year. In future years, additional efforts will be made to include the full, up-front funding requests within the Department's agency account for all new projects, or at least economically and programmatically viable segments or phases of new projects.

QUESTION FROM REPRESENTATIVE ROHRABACHER

General

Q5. We understand that significant sums, well in excess of $100 million were added in the Office of Management and Budget (OMB) passback of the FY 1997 budget for renewable energy and energy efficiency programs. Did any of these additions come from reductions to OER programs, and if so, which ones?

A5. Not that we are aware of. The Office of Management and Budget passback for Office of Energy Research programs provided an increase of $63.6 million above the request to Office of Management and Budget. This increase is primarily related to the Fusion Energy program.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Scientific Facilities Initiative

Q6. The FY 1996 request for the Scientific Facilities Initiative (SFI) was $100 million ($60 for BES, $25 million in Nuclear Physics, and $15 million in High Energy Physics).

a. For the original $100 million request, please provide a table listing, by facility, the funding for each and the number of hours of operation expected at that funding level.

A6. I will be happy to provide that information in a table for the record.

Assistant Secretary's Initials

SCIENTIFIC FACILITIES INITIATIVE
(Dollars in thousands)

	FY 1996 Initiative Increment $100 M Request	 Hours of Operation
Basic Energy Sciences		
Large BES Facilities		
Light Sources		
SSRL (Stanford)	$ 5,354	2,132
ALS (LBNL)	11,609	2,224
APS (ANL)*	5,000	0
NSLS (BNL)	7,645	523
Laser Diagnostic Lab		
CRF, Phase I (SNL)	1,000	168
Neutron Sources		
IPNS (ANL)	5,184	2,873
HFBR (BNL)	5,525	2,230
HFIR (ORNL)	6,086	2,205
LANSCE (LANL)**	4,015	0
Subtotal, Large BES Facilities	51,418	12,355
Small BES User Facilities		
Center for Micro. Of Materials (Univ. Of Illinois)	1,000	N/A
Electron Microscopy Center (ANL)	1,155	N/A
Materials Prep. Center (Ames)	1,080	N/A
NCEM (LBNL)	1,135	N/A
SHaRE (ORISE)	98	N/A
SHaRE (ORNL)	1,114	N/A
Subtotal, Small BES Facilities	5,582	N/A
Total, BES	57,000	12,355
Computational and Technology Research		
National Supercomputer Center	3,000	N/A
Total, CTR	3,000	N/A
High Energy Physics		
Fermilab	8,000	470
SLAC	4,500	425
AGS (BNL)	2,500	520
Total, HEP	15,000	1,415

* APS is under construction and will begin operation in FY 1997.

** LANSCE is upgrading the accelerator and will resume full operation in FY 1997.

	FY 1996 Initiative Increment	
	$100 M Request	Hours of Operation
Nuclear Physics		
Tandem/AGS (BNL)	2,900	800
CEBAF	14,900	1,300
RIB (ORNL)	1,500	2,600
MIT-Bates	3,500	2,500
88 Inch Cyclotron (LBNL)	1,100	960
ATLAS (ANL)	1,100	1,000
Total, NP	25,000	9,160
Total, BES/CTR/HEP/NP	**$100,000**	**22,930**

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Scientific Facilities Initiative

Q6. The FY 1996 request for the Scientific Facilities Initiative (SFI) was $100 million ($60 for BES, $25 million in Nuclear Physics, and $15 million in High Energy Physics).

b. What is the actual FY 1996 level of SFI funding?

A6. The FY 1996 appropriation for the scientific user facilities included in the initiative is $847 million compared to the FY 1996 request of $879 million. The funding for the "initiative" is included in this total. It is not possible to track the appropriation for the $100 million increment since these funds are included in the base.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Scientific Facilities Initiative

Q6. The FY 1996 request for the Scientific Facilities Initiative (SFI) was $100 million ($60 for BES, $25 million in Nuclear Physics, and $15 million in High Energy Physics).

c. For the actual FY 1996 level of SFI funding, please provide a table listing, by facility, the funding for each and the number of hours of operation expected, at the funding level.

A6. I will be happy to provide that information in a table for the record.

SCIENTIFIC USER FACILITIES
(Dollars in thousands)

	FY 1996	
	Appropriation	Hours of Operation
Basic Energy Sciences		
Large BES Facilities		
Light Sources		
SSRL (Stanford)	$ 21,459	6,275
ALS (LBNL)	34,672	5,050
APS (ANL)	85,929	N/A
NSLS (BNL)	31,238	10,565
Laser Diagnostic Lab		
CRF, Phase I (SNL)	5,106	4,205
Neutron Sources		
IPNS (ANL)	11,767	5,045
HFBR (BNL)	26,851	5,850
HFIR (ORNL)	29,425	6,245
LANSCE (LANL)	7,641	975
Pending Peer Review	16,229	N/A
Subtotal, Large BES Facilities	270,317	44,210
Small BES User Facilities		
Center for Micro. Of Materials (Univ. Of Illinois)	939	N/A
Electron Microscopy Center (ANL)	2,267	N/A
Materials Prep. Center (Ames)	985	N/A
NCEM (LBNL)	2,862	N/A
SHaRE (ORISE)	229	N/A
SHaRE (ORNL)	1,987	N/A
Subtotal, Small BES Facilities	9,269	N/A
Total, BES	279,586	44,210
Computational and Technology Research		
National Supercomputer Center	23,259	8,784
Total, CTR	23,259	8,784

			FY 1996	
			Appropriation	Hours of Operation
High Energy Physics				
	Fermilab		204,213	3,300
	SLAC		122,070	4,100
	AGS (BNL)		69,787	1,400 a/
Total, HEP			396,070	8,800
Nuclear Physics				
	Tandem/AGS (BNL)		17,930	1,000
	CEBAF		67,375	3,000-4,500b/
	RIB (ORNL)		10,125	1,500
	MIT-Bates		16,913	2,000
	88 Inch Cyclotron (LBNL)		9,618	5,400
	ATLAS (ANL)		11,116	5,000
	LAMPF (LANL)		2,900	0 c/
Total, NP			135,977	17,900-19,400
Biological and Environmental Research				
Structural Biology Beamlines				
	APS (ANL)		700	d/
	NSLS (BNL)		3,000	d/
	HFBR (BNL)		1,100	d/
	LANSCE (LANL)		500	d/
	ALS (LBNL)		3,600	d/
	NCEM (LBNL)	400	d/	
	HFIR (ORNL)		400	d/
	SSRL (Stanford)		2,100	d/
Total, BER			11,800	d/
Total, BES/CTR/HEP/NP/BER			**$846,692**	**79,694-81,194**

a/ At AGS, assume 1 week running equals 100 beam hours for research.

b/ At CEBAF, 3,000 hours without reprogramming; 4,500 with reprogramming.
At CEBAF, assume 1 week running equals 150 beam hours for research.

c/ LAMPF operating costs are supported by Defense Programs. Funding provided by Nuclear Physics supports several high priority research experiments.

d/ Included in BES operating hours above.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Scientific Facilities Initiative

Q7. For the FY 1997 requested level of SFI funding, please provide a table listing, by facility, the funding for each and the number of hours of operation expected at that funding level.

A7. I will be happy to provide that information in a table for the record.

SCIENTIFIC USER FACILITIES
(Dollars in thousands)

	FY 1997 President Request	
	Request	Hours of Operation
Basic Energy Sciences		
Large BES Facilities		
Light Sources		
SSRL (Stanford)	$ 21,001	5,935
ALS (LBNL)	35,290	4,795
APS (ANL)	85,692	4,365
NSLS (BNL)	30,565	10,060
Laser Diagnostic Lab		
CRF, Phase I (SNL)	5,245	3,990
Neutron Sources		
IPNS (ANL)	11,620	4,770
HFBR (BNL)	25,985	5,560
HFIR (ORNL)	29,665	5,825
LANSCE (LANL)	7,740	912
Pending Peer Review	13,550	N/A
Subtotal, Large BES Facilities	266,353	46,212
Small BES User Facilities		
Center for Micro. Of Materials (Univ. Of Illinois)	1,950	N/A
Electron Microscopy Center (ANL)	2,430	N/A
Materials Prep. Center (Ames)	1,069	N/A
NCEM (LBNL)	3,514	N/A
SHaRE (ORISE)	195	N/A
SHaRE (ORNL)	2,125	N/A
Subtotal, Small BES Facilities	11,283	N/A
Total, BES	277,636	46,212
Computational and Technology Research		
National Supercomputer Center	28,000	8,784
Total, CTR	28,000	8,784

	FY 1997 President Request	
	Request	Hours of Operation
High Energy Physics		
Fermilab	207,743	3,480
SLAC	125,450	4,280
AGS (BNL)	70,782	1,800 a/
Total, HEP	403,975	9,560
Nuclear Physics		
Tandem/AGS (BNL)	18,570	1,000
CEBAF	69,000	4,500
RIB (ORNL)	10,800	2,400
MIT-Bates	17,618	2,500
88 Inch Cyclotron (LBNL)	9,510	5,100
ATLAS (ANL)	11,805	4,600
LAMPF (LANL)	2,775	0 b/
Total, NP	140,078	20,100
Biological and Environmental Research		
Structural Biology Beamlines		
APS (ANL)	2,700	c/
NSLS (BNL)	2,000	c/
HFBR (BNL)	1,100	c/
LANSCE (LANL)	4,300	c/
ALS (LBNL)	1,600	c/
NCEM (LBNL)	0	c/
HFIR (ORNL)	400	c/
SSRL (Stanford)	2,300	c/
Total, BER	14,400	c/
Total, BES/CTR/HEP/NP/BER	$864,089	84,656

a/ At AGS, assume 1 week running equals 100 beam hours for research.

b/ LAMPF operating costs are supported by Defense Programs. Funding provided by Nuclear Physics supports several high priority research experiments.

c/ Included in BES operating hours above.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Scientific Facilities Initiative

Q8. It appears from the FY 1997 budget request documentation that most of the scientific user facilities will be operating at a lower level in FY 1997 than in FY 1996. For example, overall funding for the 10 Basic Energy Sciences Major User Facilities would be reduced by over $2.2 million in FY 1997, and High Energy Physics Facilities Operations are below FY 1996 levels at Fermilab, SLAC and Brookhaven. Why is this the case, and what is the reason for the apparent waning of DOE support for the Scientific User Facilities Initiative?

A8. The funding in FY 1996 for the 10 Basic Energy Sciences facilities is $236.5 million. The funding in FY 1997 is $234.3 million. The reduction is based on the Department's planned streamlining savings.

Funding for the Department's scientific user facilities in the High Energy Physics program at Fermilab, SLAC and AGS is up from $396.1 million in FY 1996 to $404.0 million in FY 1997.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Scientific Facilities Initiative

Q9. With regard to the Advanced Photon Source (APS) at Argonne, which was just dedicated on May 1, we understand that there is a significant funding shortfall for FY 1997 in DOE's budget request. What are the implications of this funding shortfall?

A9. There is no shortfall. The amount in the President's Request is adequate to operate the facility even though it is less than Argonne's full request.

Argonne's proposed budget for operations is $69.1 million including utilities, management, personnel, maintenance, environmental, health, and safety costs.

The Argonne proposed budget also includes $19 million for programmatic research related to the facility.

The President's budget of $80 million includes the full amount for operations and $11 million for programmatic research related to the facility. Since this is a new facility, we anticipate that $11 million for programmatic research related to the facility will be adequate. A recent review by the Basic Energy Sciences Advisory Committee of the operating funding requirements for steady-state operations recommended a total budget in $79-83 million range with a substantially reduced level of programmatic research related to the facility.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Life Sciences

Q10. Please provide the level of funding for each DOE Laboratory for each Life Sciences program activity (i.e., Structural Biology, Molecular and Cellular Biology, Human Genome, and Health Effects) for each of FY 1995, FY 1996, and FY 1997.

A10. I will be happy to provide that information in a table for the record.

Biological & Environmental Research
Life Sciences
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Structural Biology			
Argonne National Laboratory	$2,855	$3,655	$2,722
Brookhaven National Laboratory	6,074	5,520	5,911
Lawrence Berkeley National Laboratory	2,634	2,610	2,610
Lawrence Livermore National Laboratory	280	0	0
Los Alamos National Laboratory	604	506	486
Oak Ridge National Laboratory	600	400	534
Pacific Northwest National Laboratory	379	0	0
Stanford Linear Accelerator Laboratory	1,379	1,650	1,212
Molecular & Cellular Biology			
Argonne National Laboratory	$ 292	$ 300	$ 195
Brookhaven National Laboratory	1,600	1,612	1,579
Lawrence Berkeley National Laboratory	1,599	1,790	1,256
Lawrence Livermore National Laboratory	2,348	1,650	2,208
Los Alamos National Laboratory	2,491	2,379	2,197
Oak Ridge Institute for Science and Education	451	319	0
Oak Ridge National Laboratory	4,437	4,245	4,387
Pacific Northwest National Laboratory	520	0	292
Human Genome			
Ames Laboratory	$ 269	$ 269	$ 264
Argonne National Laboratory	1,884	1,667	1,885
Brookhaven National Laboratory	2,156	2,513	2,811
Lawrence Berkeley National Laboratory	10,615	11,486	10,892
Lawrence Livermore National Laboratory	9,600	9,777	9,347
Los Alamos National Laboratory	11,121	9,866	10,585
Oak Ridge Institute for Science and Education	532	40	879
Oak Ridge National Laboratory	3,277	3,507	3,130
Pacific Northwest National Laboratory	532	500	521

Health Effects

	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	$3,775	$1,475	$1,445
Brookhaven National Laboratory	347	60	362
Idaho National Engineering Laboratory	0	5	0
Lawrence Berkeley National Laboratory	3,055	3,310	2,370
Lawrence Livermore National Laboratory	998	1,480	678
Los Alamos National Laboratory	1,784	1,470	1,542
Oak Ridge Institute for Science and Education	1,387	175	1,533
Oak Ridge National Laboratory	4,555	2,950	3,720
Pacific Northwest National Laboratory	3,985	260	196

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Life Sciences

Q11. One of the FY 1997 planned accomplishments for Life Sciences is to "Complete production and broadcast of radio series on genome research and television documentary on ELSI, 'Genetics and Society'" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p.185).

a. Please provide a detailed accounting of the costs of producing and broadcasting the radio series on genome research, including identification of funding recipients to date and projected total costs.

A11. In Fiscal Year 1995, a two-year grant was awarded for "The Genome Radio Project" to the Pacifica Foundation the sole grantee. The sole purpose of this grant is to enhance public understanding of both the science and some of the societal implications of the Human Genome Program. The Department of Energy grant will pay for only about one-half of this project. The total Department of Energy projected award is $358,000. The budget for this project includes salaries and benefits for senior project personnel, production personnel, technical staff, and marketing outreach and promotion staff, as well as contract personnel and consultants, acquisition of research materials, rights payments, advisory board/consultant meetings, travel, studio costs, production supplies, equipment rental and maintenance, equipment purchases, marketing and publicity, program and digital distribution, and administration and evaluation costs. The Department of Energy funding is for preparation and production costs only. The programs have not yet been broadcast.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Life Sciences

Q11. One of the FY 1997 planned accomplishments for Life Sciences is to "Complete production and broadcast of radio series on genome research and television documentary on ELSI, 'Genetics and Society'" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p.185).

b. Please provide a detailed accounting of the costs of producing and broadcasting the television documentary on ELSI, "Genetics and Society," including identification of funding recipients to date and projected total costs.

A11 In Fiscal Year 1995, a two-year award for a television documentary project entitled, "Genetics in Society," was made to Oregon Public Broadcasting, the sole grantee. The sole purpose of this grant is to enhance public understanding of both the science and some of the societal implications of the Human Genome Program. The total Department of Energy award is expected to be $400,000, and will fund approximately one-fifth of the total cost of the project. The budget for this project includes salaries and benefits for senior project and production personnel, administrative, research, production, advisor and host travel, administration, talent and fees, production, post-production and editing costs, educational and outreach costs, and evaluation costs. The $400,000 awarded by the Department of Energy is identified for use towards education and outreach exclusively. The programs have not yet been broadcast.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Life Sciences

Q11. One of the FY 1997 planned accomplishments for Life Sciences is to "Complete production and broadcast of radio series on genome research and television documentary on ELSI, 'Genetics and Society'" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p.185).

c What is the rationale for the use of scarce research dollars to fund such efforts?

A11. Since the outset of the Human Genome Program in 1989, it has been widely recognized in Congress, the administration, the scientific community, and in society at large that the consequences of mapping and sequencing the human genome include ethical, legal, and societal implications ("ELSI") that could complicate the realization of the medical, scientific, and commercial benefits widely expected from this project. Among the many ELSI issues identified early on, the Department of Energy elected to focus on two, privacy and education. Privacy concerns may arise when genetic information is used to determine insurability or employability or to classify people without their knowledge. Modern genetics is often complex, technical, and difficult to explain, but of such importance that efforts to communicate its content and implications are a priority. The radio series and the television documentary series are within this high priority area of education and are consistent with the long-standing interest of the Department of Energy in science education.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Life Sciences

Q12. One of the FY 1997 planned accomplishments for Life Sciences says "Funding in the amount of $3,446,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development,* DOE/CR-0035, Volume 2 of 5, p.185). However, the narrative also states that $2,649,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (30.0 percent) for SBIR?

A12. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Life Sciences

Q13. The FY 1997 request for Health Effects research is a reduction of 8.4 percent below FY 1996 and a reduction of 63.3 percent below FY 1995. According to the FY 1997 budget documents, these decreases are the result of phasing out of most research in radiation biology. Why is this research being terminated?

A13. Budget cuts in the FY 1996 and FY 1997 Health Effects portion of the Biological and Environmental Research (BER) Program required this office to set priorities and make programmatic choices. A great deal of additional research in the field of radiation biology would indeed be valuable, but due to the Biological and Environmental Research Program and its predecessors, more is now known about the effects of radiation than for any other potential carcinogen. As a result, radiation biology is not as high a priority as other research in the Biological and Environmental Research Program (e.g. Human Genome, Microbial Genome, Structural Biology, etc.).

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER):Environmental Processes

Q14. Please provide the level of funding for each DOE Laboratory for each Environmental Sciences program activity (i.e., Climate and Hydrology, Atmospheric Chemistry and Carbon Cycle, Ecological Processes, and Human Interactions) for each of FY 1995, FY 1996 and FY 1997

A14. I will be happy to provide that information in a table for the record

Biological & Environmental Research
Environmental Processes
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Climate and Hydrology			
Argonne National Laboratory	$ 834	$ 816	$ 944
Brookhaven National Laboratory	780	548	535
Lawrence Berkeley National Laboratory	342	0	0
Lawrence Livermore National Laboratory	6,121	5,700	5,602
Los Alamos National Laboratory	5,038	3,091	4,023
Oak Ridge National Laboratory	1,805	1,837	1,806
Pacific Northwest National Laboratory	17,159	19,778	21,817
Sandia National Laboratory	1,335	1,342	1,318
Atmospheric Chemistry and Carbon Cycle			
Argonne National Laboratory	$1,117	$1,527	$ 395
Brookhaven National Laboratory	4,214	3,547	3,802
Lawrence Berkeley National Laboratory	150	147	145
Lawrence Livermore National Laboratory	457	454	219
Los Alamos National Laboratory	530	617	0
Oak Ridge Institute for Science and Education	30	0	0
Oak Ridge National Laboratory	970	1,246	1,032
Pacific Northwest National Laboratory	4,661	3,084	3,182
Westinghouse Savannah River	148	148	0
Ecological Processes			
Argonne National Laboratory	$ 344	$ 415	$ 344
Brookhaven National Laboratory	1,319	1,317	1,285
Lawrence Livermore National Laboratory	23	150	144
Los Alamos National Laboratory	193	194	187
Oak Ridge National Laboratory	1,760	1,984	1,659
Pacific Northwest National Laboratory	196	194	187

	FY 1995	FY 1996	FY 1997
Human Interactions			
Argonne National Laboratory	$ 30	$ 61	$ 0
Lawrence Berkeley National Laboratory	188	209	0
Oak Ridge Institute for Science and Education	2,411	2,281	2,794
Oak Ridge National Laboratory	2,143	2,295	1,690
Pacific Northwest National Laboratory	560	701	244

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Environmental Processes

Q15. Please provide the level of Environmental Processes funding for each of FY 1995, FY 1996 and FY 1997 for (a) the Atmospheric Radiation Measurement (ARM) program, (b) CHAMMP, (c) the National Institute for Global and Environmental Change, (d) graduate and post-doctoral fellowships and all other types of education activities.

A15. I will be happy to provide that information in a table for the record.

Biological & Environmental Research
Environmental Processes
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Atmospheric Radiation Measurement (ARM)	$37,829	$38,221	$41,251
Computer Hardware, Advanced Mathematics And Model Physics (CHAMMP)	9,962	9,768	10,667
National Institute for Global and Environmental Change (NIGEC)	9,270	9,000	9,000
Education Activities including Fellowships	2,131	2,131	2,540

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Environmental Processes

Q16. Please provide a listing of all projects/efforts funded by the Human Interactions activity for each of FY 1994, FY 1995, and FY 1996. For each such project/effort, please provide the name of the performing entity and a brief description.

A16. I will be happy to provide FY 1995, FY 1996, and FY 1997 information in a table for the record.

BIOLOGICAL AND ENVIRONMENTAL RESEARCH
Human Interactions
(B/A in thousands)

Performing Entity/Project Title	FY 1995	FY 1996	FY 1997
ADVANCED RESEARCH PROJECTS AGENCY			
Summer workshop on benefit cost issues and DOE waste management	$ 50	$ 0	$ 0
ARGONNE NATIONAL LABORATORY			
Development & Application of a Taxonomy of Global Climate Change Surprises	30	61	0
UNIVERSITY OF CALIFORNIA			
National Institute for Global Environmental Change (NIGEC) - Individual research projects at 10-15 universities on impacts of climate change	1,854	1,796	1,800
Learning & Enhanced Climate Representation in Integrated Assessment Models	202	0	202
CARNEGIE MELLON UNIVERSITY			
Core Support for Comprehensive Integrated Assessment Of Climate Change	324	0	250
ENERGY INFORMATION ADMINISTRATION			
Energy Modeling Forum for Comparison of Integrated Assessment Models	65	50	0
HARVARD UNIVERSITY			
Economic and Energy Development in China-Policy Options and Implications for Climate Change	311	0	0
Assessment Strategies for Global Environmental Change	637	0	0

	FY 1995	FY 1996	FY 1997
LAWRENCE BERKELEY NATIONAL LABORATORY			
Structural Models of Long Term Energy Demand	$ 128	$ 149	$ 0
Modelling Technology Diffusion for Climate Change	0	20	0
Inter-generational issues in Integrated Assessment	60	40	0
MASSACHUSETTS INSTITUTE OF TECHNOLOGY			
Research on Economics of Global Change	0	0	250
Integrated Framework for Climate Change Assessment	248	0	0
NATIONAL SCIENCE FOUNDATION			
Update of the Glossary of Meteorology	0	0	28
NEW YORK UNIVERSITY			
Models, Linkages and Feedbacks in Integrated Assessments of Global Change	85	0	0
OAK RIDGE INSTITUTE FOR SCIENCE & EDUCATION			
Technical Review of CO2 Research Initiatives	300	150	254
Postdoctoral Fellowships for Global Change	1,100	1,100	1,563
Graduate Fellowships for Global Change	1,011	1,031	977
OAK RIDGE NATIONAL LABORATORY			
Research on adoption of new technologies	80	88	0
Support of Carbon Dioxide Information Center	1,928	2,012	1,690
Data Support for Integrated Assessment Research	50	198	0
Contingent Valuation Methods Applied to Developing Countries	80	70	0

	FY 1995	FY 1996	FY 1997
PACIFIC NORTHWEST NATIONAL LABORATORY			
Global Climate Change and the Social Sciences - Integrated Assessment Modeling	$ 250	$ 250	$ 244
Supporting Assessments for United States Global Change Research Program (USGCRP)	210	210	0
Compact Structural Model of Residential and Commercial Buildings for IA	20	92	0
State of Art Report in Integrated Assessment - Assessment Of what is known and not known about social sciences Aspects of climate change	60	50	0
Use of Integrated Assessment Model to Conduct Sensitivity Analyses	20	99	0
PRINTING			
Global Change Research Summaries of Research in FY 1994	11	12	0
RESOURCES FOR THE FUTURE			
Global Change and the Value of Biodiversity for New Product Research	86	0	0
SANTA FE INSTITUTE			
Research Program on Science of Complexity	32	0	0
STANFORD UNIVERSITY			
Workshops on Representing Climate Impacts in Integrated Assessment Models	175	0	0
HEADQUARTERS			
Peer Review and SBIR/STTR	202	1503	2200

	FY 1995	FY 1996	FY 1997
YALE UNIVERSITY			
Comparison of Alternative Methods to Measure the Economic Implications of Climate Change on Recreation	$ 32	$ 0	$ 0
Integrating Ecology and Economics to Measure the Impact of Climate Change On Global Timber Markets	92	0	0
TOTAL HUMAN INTERACTIONS	9,733	8,981	9,458

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Environmental Processes

Q17. One of the FY 1997 planned accomplishments for Environmental Processes says that "Funding in the amount of $2,126,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development,* DOE/CR-0035, Volume 2 of 5, p.190). However, the narrative also states that $1,526,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (39.3 percent) for SBIR?

A17. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P L. 102-564 That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Environmental Remediation

Q18. Please provide the level of funding for each DOE Laboratory for the Environmental Remediation program for each of FY 1995, FY 1996 and 1997.

A18. I will be happy to provide that information in a table for the record.

Biological & Environmental Research
Environmental Remediation
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	$ 488	$ 200	$ 193
Brookhaven National Laboratory	261	150	242
Idaho National Engineering Laboratory	675	815	823
Lawrence Berkeley National Laboratory	920	340	387
Los Alamos National Laboratory	222	204	0
Oak Ridge Institute for Science & Education	50	0	47
Oak Ridge National Laboratory	1,420	1,130	1,190
Pacific Northwest National Laboratory	6,380	5,360	10,679

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Medical Applications and Measurement Science

Q19. Please provide the level of funding for each DOE Laboratory for each Medical Applications and Measurement Science program activity (i.e., Medical Applications, and Measurement Science) for each of FY 1995, FY 1996 and 1997.

A19. I will be happy to provide that information in a table for the record.

Biological & Environmental Research
Medical Applications and Measurement Science
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Medical Applications			
Brookhaven National Laboratory	$10,277	$9,992	$9,631
Fermi National Accelerator Laboratory	1,050	1,575	2,100
Idaho National Engineering Laboratory	2,480	1,250	1,430
Lawrence Berkeley National Laboratory	2,097	2,195	2,028
Los Alamos National Laboratory	779	638	595
Oak Ridge Institute for Science and Education	314	225	234
Oak Ridge National Laboratory	1,248	1,023	1,077
Measurement Science			
Ames Laboratory	$ 309	$ 327	$ 317
Argonne National Laboratory	282	0	0
Brookhaven National Laboratory	100	195	189
Idaho National Engineering Laboratory	145	198	192
Lawrence Berkeley National Laboratory	425	337	326
Lawrence Livermore National Laboratory	57	0	0
Los Alamos National Laboratory	0	300	0
Oak Ridge National Laboratory	1,259	877	876
Pacific Northwest National Laboratory	358	375	0

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Medical Applications and Measurement Science

Q20. Please provide the level of Medical Applications and Measurement Science funding for each of FY 1995, FY 1996 and 1997 for Boron Neutron Capture Therapy (BNCT).

A20. I will be happy to provide that information in a table for the record.

Biological & Environmental Research
Medical Applications and Measurement Science
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Boron Neutron Capture Therapy (BNCT)	$9,913	$9,615	$9,727

QUESTION FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Medical Applications and Measurement Science

Q21. The FY 1997 budget request for Medical Applications and Measurement Science is reduced from the FY 1996 level primarily due to the completion of Congressional earmarks of $7.0 million for the Biomedical Research Foundation of northwest Louisiana and another $8.5 million for the Oregon Health Sciences University. What benefits are taxpayers to receive from these earmarks, and how were these funds use?

A21. The Department of Energy has not yet received applications from the Biomedical Research Foundation of Northwest Louisiana, hence the funds earmarked in the Fiscal Year 1996 appropriation have not yet been awarded. It is, therefore, not possible to discuss how these funds are to be used, or the benefits to the taxpayers from these earmarks. However, discussions have taken place between staff of the Department and of the Biomedical Research Foundation of Northwest Louisiana about the potential content of their application. The application is likely to include projects applying technologies developed at the Department of Energy national laboratories in clinical medicine, with particular benefit to the region served by the Foundation.

The Oregon Health Sciences University application has been received and is being processed for FY 1996 funding. The research will explore and implement the design of an advanced multimedia network and information system to facilitate the exchange of health information and health records, and enhance communications between health care providers. A collaboration with the Oregon Graduate Institute Computer Sciences Division will be initiated to design a high-speed multimedia data network prototype.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Biological and Environmental Research (BER): Related Capital Funding

Q22. Please provide the level of funding for each DOE Laboratory for each Related Capital Funding program activity (i.e., Capital Equipment, General Plant Projects, and Facility Modifications and Improvements) for each of FY 1995, FY 1996 and 1997.

A22. **I will be happy** to provide that information in a table for the record.

Biological & Environmental Research
Related Capital Funding
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Capital Equipment			
Ames Laboratory	$ 79	$ 0	$ 0
Argonne National Laboratory	717	600	195
Brookhaven National Laboratory	3,923	350	685
Environmental Measurements Laboratory	250	0	0
Idaho National Engineering Laboratory	40	58	0
Lawrence Berkeley National Laboratory	3,828	4,453	3,035
Lawrence Livermore National Laboratory	643	1,197	587
Los Alamos National Laboratory	985	942	587
Oak Ridge Institute for Science and Education	469	0	175
Oak Ridge National Laboratory	696	200	335
Pacific Northwest National Laboratory	8,803	9,935	10,300
Stanford Linear Accelerator Laboratory	2,050	500	195
General Plant Projects			
Lawrence Livermore National Laboratory	$ 800	$1,100	$ 500
Los Alamos National Laboratory	1,558	140	400
Oak Ridge Institute for Science and Education	1,350	200	450
Pacific Northwest National Laboratory	400	2,000	2,100
Facility Modifications and Improvements			
Brookhaven National Laboratory	$ 0	$ 0	$1,500

QUESTION FROM REPRESENTATIVE ROHRABACHER

Fusion Energy Sciences

Q23. It is our understanding that DOE's initial request for Fusion submitted to the Office of Management and Budget (OMB) was $200 million. And here we have before us a final FY 1997 request of $255.6 million. Where did the $55.6 million come from? What specific reductions did other OER programs incur in order to fund this request?

A23. There were a number of adjustments made to the Department's FY 1997 budget request by the Office of Management and Budget (OMB). The OMB passback for OER programs provided an increase of $63.6 million above the request. This increase is primarily related to the Fusion Energy Sciences program.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Fusion Energy Sciences

Q24. The FY 1997 request for Fusion Energy Sciences continues the past practice of funding expensive upgrades (e.g., $32.4 million total estimated cost for the DIII-D upgrade) and construction of new devices (e.g., $18.0 million total estimated cost for the proposed National Spherical Tokamak Experiment at Princeton Plasma Physics Laboratory). Why is this? Why should fusion device construction projects not go through the normal process as do other DOE construction projects?

A24. Continued progress in many fields of science, including fusion, typically requires facilities of ever increasing capability and performance. As initially constructed, these facilities are not fully equipped to realize their ultimate scientific and technical potential, simply because it is more cost effective to use the results from initial experiments to optimize the planning of facility upgrades. In the case of upgrading DIII-D, technical developments have already allowed a significant reduction in its originally envisioned scope and cost. Given the sizable investment already made in DIII-D, it makes good sense to extend its research capability in this manner. The present plan, already half implemented, provides for a new heat removal (divertor) system, additional plasma heating capacity and extended pulse length.

The proposed National Spherical Tokamak Experiment, which would test an alternative fusion concept at the proof-of-principle level, is a departure from past practice both in terms of its much smaller cost (when compared with $742 million for the now canceled Tokamak Physics Experiment) and construction approach, which is to modify an existing device (the S-1 Spheromak) at Princeton and reuse other available equipment and infrastructure. It would thus leverage a modest investment into a facility of much greater capability than one built from scratch for the same cost.

New fusion devices proposed for construction (e.g., Tokamak Physics Experiment) have always been subject to the same policies and procedures which govern all Department of Energy construction projects. Modifications to existing facilities (also referred to as upgrades) and relatively small experiments are handled in a different way because they are not funded as line item construction projects. Despite this difference, they still undergo technical, cost and schedule reviews as part of the Department's management oversight process.

In addition, the program uses peer reviews to review scientific proposals plus advisory committees for each of the major facilities as well as the Fusion Energy Science Advisory Committee on broader program issues.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Fusion Energy Sciences

Q25. How much is contained in the FY 1997 budget request for Heavy Ion Fusion?

A25. $8.0 million has been requested for Heavy Ion Fusion research in FY 1997 as a placeholder in the budget process pending a review of the Inertial Fusion Energy program by the Fusion Energy Advisory Committee.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Fusion Energy Sciences

Q26. The FY 1997 budget documents indicate that DOE intends to continue to participate in the International Thermonuclear Experimental Reactor (ITER) Engineering Design Activities (EDA) into FY 1998, and to begin negotiating its participation in ITER construction. When are these negotiations scheduled to begin, and what does DOE intend to bring to the table?

A26. To allow for decisions on construction and operation before the end of the Engineering Design Activities, thereby minimizing the likelihood of a costly hiatus, the start of formal negotiations is tentatively projected for July 1997

To determine whether such formal negotiations could be successful, noncommittal, pre-negotiation, exploratory discussions were tentatively projected to start in July 1996.

The Department of Energy, in concert with other Administration agencies, already having decided not to offer to host, decided in mid-July to enter these exploratory discussions, which began in late July.

This decision to enter exploratory discussions was made with the clear understanding by the other Parties that there are no financial preconditions on participation in the discussions and that the discussions will focus mainly on siting, licensing and host support and related issues with cost sharing reserved for any future negotiations.

One of the new policy goals of the restructured fusion program is pursuit of fusion energy sciences through partnership in the International Thermonuclear Experimental Reactor-based international effort aimed at fusion energy goals. This goal will guide our development of the United States objectives for International Thermonuclear Experimental Reactor participation and of what we could bring to the table.

We have identified a number of areas of scientific and technical excellence, such as advanced confinement modes and advanced diagnostics, including both design, research and development and operation where our financially limited contribution could be highly valuable to the project.

Even with the financial limitations, it is our informal understanding that the other Parties strongly seek our involvement because of the significant technical knowledge base, developed over decades, represented in our personnel as well as the value of United States participation in the leadership of such a complex undertaking.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Fusion Energy Sciences

Q27. One of the FY 1997 planned accomplishments for Environmental Processes says that "Funding in the amount of $3,800,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p. 233). However, the narrative also states that $3,070,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (23.8 percent) for SBIR?

A27. Although the question references Environmental Processes, the page referred to is pertinent to Fusion Energy Sciences. Therefore, the answer provided is for Fusion Energy Sciences.

The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Materials Sciences

Q28. Please provide the level of funding for each DOE Laboratory for each Materials Sciences Program Activity (i.e., Materials Sciences Research, and Facilities Operations) for each of FY 1995, FY 1996 and 1997.

A28. I will be happy to provide that information in a table for the record.

Basic Energy Sciences
Materials Sciences
(B/A in thousands)

Research	FY 1995	FY 1996	FY 1997
Ames Laboratory	$9,529	$9,602	$9,806
Argonne National Laboratory	17,540	16,914	16,119
Brookhaven National Laboratory	9,895	10,349	10,304
Idaho National Engineering Laboratory	733	722	692
Lawrence Berkeley National Laboratory	15,402	15,137	14,638
Lawrence Livermore National Laboratory	2,885	3,130	3,451
Los Alamos National Laboratory	6,999	7,292	6,655
National Renewable Energy Laboratory	1,086	1,723	1,282
Oak Ridge Institute for Science and Education	285	565	264
Oak Ridge National Laboratory	22,065	28,998	26,171
Pacific Northwest National Laboratory	3,614	3,064	3,430
Sandia National Laboratory	8,186	7,732	7,813

Facilities Operations	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	$71,571	$89,538	$90,970
Brookhaven National Laboratory	37,520	42,306	42,875
Lawrence Berkeley National Laboratory	21,200	28,616	28,945
Los Alamos National Laboratory	0	6,688	6,740
Stanford Linear Accelerator Center	2,756	3,515	3,550

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Materials Sciences

Q29. The FY 1997 budget request for Materials Sciences includes another $8.0 million, the same as in FY 1996, for continued work on a new spallation neutron source. What is the proposed schedule for this source and what are the outyear budgetary implications?

A29. The $8 million in the request is to complete the Conceptual Design that will give the cost and schedule for the project.

Based on preliminary feasibility studies, the cost of the facility should be in the range of $1 billion in 1996 dollars and could be completed in 2004 if started in FY 1998.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Materials Sciences

Q30. The FY 1997 budget request also says that the Materials Sciences program intends to support the development of options for upgrading existing reactor and spallation sources as near-term solutions for providing neutrons while the next-generation spallation neutron source is being pursued.

a: What specific options are being developed?

A30. Options being considered are based on the recommendations of the Basic Energy Sciences Advisory Committee.

The recommendation included an upgrade of the High Flux Beam Reactor at Brookhaven National Laboratory to provide enhanced cold neutron scattering capability, an upgrade of the High Flux Isotope Reactor at Oak Ridge National Laboratory to provide enhanced thermal neutron scattering capability, joint Defense Programs-Energy Research development of a long-pulse spallation source at Los Alamos National Laboratory and an option for a short-pulse spallation source upgrade in the 160 kilowatt range at Los Alamos National Laboratory

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Materials Sciences

Q30 The FY 1997 budget request also says that the Materials Sciences program intends to support the development of options for upgrading existing reactor and spallation sources as near-term solutions for providing neutrons while the next-generation spallation neutron source is being pursued.

b: What are the proposed schedules for these options and what are the outyear budgetary implications?

A30. No decisions have been made as to which upgrades to pursue. Firm cost estimates and schedules will not be available until the completion of Conceptual Designs for those upgrades that will be pursued.

Based on preliminary feasibility studies the combined cost of the options is in the $250 million range and could be completed by the year 2004, if all are pursued.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Materials Sciences

Q31. One of the FY 1997 planned accomplishments for Materials Sciences says that "Funding in the amount of $8,364,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p. 255) However, the narrative also states that $6,559,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (27.6 percent) for SBIR?

A31. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P L. 102-564. That legislation called for the SBIR set aside to increase from 2 0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997 The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Chemical Sciences

Q32. Please provide the level of funding for each DOE Laboratory for each Chemical Sciences Program Activity (i.e., Chemical Sciences Research, and Facilities Operations) for each of FY 1995, FY 1996 and 1997.

A32. I will be happy to provide that information in a table for the record.

Basic Energy Sciences
Chemical Sciences
(B/A in thousands)

Research	FY 1995	FY 1996	FY 1997
Ames Laboratory	$ 3,589	$ 3,594	$ 3,594
Argonne National Laboratory	15,901	15,796	15,796
Brookhaven National Laboratory	9,843	9,503	9,303
Idaho National Engineering Laboratory	306	306	306
Lawrence Berkeley National Laboratory	8,294	7,519	7,494
Lawrence Livermore National Laboratory	290	290	290
Los Alamos National Laboratory	1,024	1,009	801
National Renewable Energy Laboratory	1,899	2,001	2,001
Oak Ridge Institute for Science and Education	170	160	160
Oak Ridge National Laboratory	10,825	9,668	9,928
Pacific Northwest National Laboratory	6,392	6,242	6,242
Sandia National Laboratory	3,374	3,164	3,164

Facilities Operations	FY 1995	FY 1996	FY 1997
Brookhaven National Laboratory	$ 7,071	$ 8,025	$ 8,100
Oak Ridge National Laboratory	31,318	34,159	34,475
Sandia National Laboratory	4,171	4,402	4,445
Stanford Linear Accelerator Center	10,731	14,143	14,245

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Chemical Sciences

Q33. One of the FY 1997 planned accomplishments for Chemical Sciences says that "Funding in the amount of $4,334,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p 266). However, the narrative also states that $3,458,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (25.3 percent) for SBIR?

A33. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Engineering and Geosciences

Q34. Please provide the level of funding for each DOE Laboratory for each Engineering and Geosciences Program Activity (i.e., Engineering Research, and Geosciences Research) for each of FY 1995, FY 1996 and 1997.

A34. I will be happy to provide that information in a table for the record.

Basic Energy Sciences
Engineering and Geosciences
(B/A in thousands)

Engineering Research	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	$ 195	$ 0	$ 0
Idaho National Engineering Laboratory	2,214	1,614	1,812
Lawrence Berkeley National Laboratory	278	0	0
Lawrence Livermore National Laboratory	200	0	0
Los Alamos National Laboratory	200	0	95
Oak Ridge National Laboratory	1,418	1,100	1,195
Pacific Northwest National Laboratory	50	0	0
Sandia National Laboratory	515	0	286

Geosciences Research			
Argonne National Laboratory	$ 656	$ 600	$ 551
Brookhaven National Laboratory	460	428	399
Idaho National Engineering Laboratory	119	65	0
Lawrence Berkeley National Laboratory	1,897	1,755	1,314
Lawrence Livermore National Laboratory	1,920	1,890	812
Los Alamos National Laboratory	2,241	1,960	884
Oak Ridge National Laboratory	1,139	1,251	960
Pacific Northwest National Laboratory	665	684	576
Sandia National Laboratory	1,313	1,515	765

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Engineering and Geosciences

Q35 One of the FY 1997 planned accomplishments for Engineering Research says that "Funding in the amount of $439,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p 265). However, the narrative also states that $350,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (25 4 percent) for SBIR?

A35 The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2 0 percent of the Department's extramural R&D budget in FY 1996 to 2 5 percent in FY 1997 The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Engineering and Geosciences

Q36. One of the FY 1997 planned accomplishments for Geosciences Research says that "Funding in the amount of $593,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p. 266). However, the narrative also states that $410,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (44.6 percent) for SBIR?

A36. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Energy Biosciences

Q37. Please provide the level of funding for each DOE Laboratory for Energy Biosciences for each of FY 1995, FY 1996 and 1997.

A37. I will be happy to provide that information in a table for the record

Basic Energy Sciences
Energy Biosciences
(B/A in thousands)

Energy Biosciences	FY 1995	FY 1996	FY 1997
Brookhaven National Laboratory	$1,045	1,050	1,036
Lawrence Berkeley National Laboratory	1,005	1,010	1,036
Los Alamos National Laboratory	131	131	129
National Renewable Energy Laboratory	135	135	133

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Energy Biosciences

Q38. One of the FY 1997 planned accomplishments for Energy Biosciences says that "Funding in the amount of $705,000 has been budgeted for the SBIR program: (*FY 1997 Congressional Budget Request: Energy Supply Research and Development,* DOE/CR-0035, Volume 2 of 5, p. 269). However, the narrative also states that $562,000 has been budgeted for SBIR in FY 1996 Why is there such a large increase (25 4 percent) for SBIR?

A38. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Related Capital Funding

Q39. Please provide the level of funding for each DOE Laboratory for each Related Capital Funding program activity (i.e., Capital Equipment, General Plant Projects, and Facility Modifications and Improvements) for each of FY 1995, FY 1996 and 1997.

A39. I will be happy to provide that information in a table for the record.

Basic Energy Sciences
Related Capital Funding
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Capital Equipment			
Ames Laboratory	$ 1,812	$ 2,392	$ 2,302
Argonne National Laboratory	10,953	14,902	9,958
Brookhaven National Laboratory	3,741	5,036	5,150
Idaho National Engineering Laboratory	288	317	328
Lawrence Berkeley National Laboratory	4,542	5,629	5,964
Lawrence Livermore National Laboratory	414	348	357
Los Alamos National Laboratory	1,060	2,200	1,968
National Renewable Energy Laboratory	413	378	374
Oak Ridge National Laboratory	9,882	6,378	9,094
Pacific Northwest National Laboratory	1,038	1,142	1,016
Stanford Linear Accelerator Center	1,619	3,221	2,566
Sandia National Laboratory	2,239	2,012	2,448
Accelerator and Reactor Improvements and Modifications			
Argonne National Laboratory	$ 0	$ 280	$3,100
Brookhaven National Laboratory	2,374	5,555	3,300
Lawrence Berkeley National Laboratory	1,780	900	2,620
Oak Ridge National Laboratory	0	0	0
Stanford Linear Accelerator Center	495	370	385
General Plant Projects			
Ames Laboratory	$545	$440	$525
Argonne National Laboratory	2,180	4,295	5,085
Sandia National Laboratory	225	80	100
Stanford Linear Accelerator Center	494	210	250

QUESTION FROM REPRESENTATIVE ROHRABACHER

Basic Energy Sciences (BES): Experimental Program to Stimulate Research (EPSCoR)

Q40. Please provide the level of DOE funding for EPSCoR, by recipient institution, for each of FY 1993, FY 1994, FY 1995, FY 1996, and FY 1997.

A40. The Department of Energy inaugurated its EPSCoR program in FY 1991 to assist the 18 EPSCoR states and the territory of Puerto Rico to become more competitive for Federal research support. Since that time, all of the states have received planning dollars, 14 of the states have received traineeship awards to support graduate students, and 9 of the states have received research implementation awards. DOE/EPSCoR has been particularly effective in leveraging the federal research dollar as the participating states have contributed over $28 million in matching support.

The FY 1996 applications for renewal of research awards are currently under review and awards will be announced in late July. The maximum award available in FY 1996 is $1.0 million per state. In FY 1997 we anticipate that there will be 9 states competing for renewal awards. The total panned level of funding in both FY 1996 and FY 1997 is $7 million.

I will be happy to provide an award summary for FY 1993, FY 1994, and FY 1995 and a list of recipient institutions for the record.

B/A in whole dollars

DOE/EPSCoR Award Summary

Institution	FY 1993	FY 1994	FY 1995
University of Alabama	$ 20,000	$1,250,000	
University of Arkansas	$ 20,000	$ 20,000	
University of Idaho	$ 20,000	$ 270,000	
Kansas State University	$ 20,000	$ 20,000	
University of Kentucky	$1,246,274	$ 250,000	
Louisiana Board of Regents	$1,039,950	$1,248,941	
Maine Science and Technology Foundation	$1,249,944	$ 200,000	$1,250,000
University of Southern Mississippi	$ 20,000	$ 20,000	
University of Montana	$ 890,407	$ 250,000	$1,238,343
University of Nebraska	$ 20,000	$ 20,000	
University of Nevada	$ 20,000	$1,450,000	
North Dakota State University	$ 20,000	$ 220,000	
University of Oklahoma	$ 20,000	$ 220,000	
University of Puerto Rico	$ 20,000	$1,250,000	
University of South Carolina	$ 20,000	$ 20,000	$1,250,000
South Dakota State University	*	$ 100,000	
University of Vermont	$ 20,000		
West Virginia University	$ 20,000	$ 220,000	
University of Wyoming	$ 20,000	$ 220,000	$1,092,949

* Did Not Apply

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q41. Please provide the level of funding for each DOE Laboratory for each CTR Program Activity (i.e., Mathematical, Information, and Computational Sciences; Laboratory Technology Research, Advanced Energy Projects, and Related Capital Funding) for each of FY 1995, FY 1996, and 1997.

A41. I will be happy to provide that information in a table for the record.

Computational and Technology Research
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Mathematical, Information, and Computational Sciences			
Ames Laboratory	$5,098	$5,011	$4,570
Argonne National Laboratory	11,208	9,443	6,458
Brookhaven National Laboratory	875	863	300
Continuous Electron Beam Accelerator Facility	385	150	180
Fermi National Accelerator Laboratory	45	0	0
Idaho National Engineering Laboratory	100	95	0
Lawrence Berkeley National Laboratory	4,573	26,791	42,259
Lawrence Livermore National Laboratory	44,881	17,061	710
Oak Ridge National Laboratory	12,765	11,557	12,148
Pacific Northwest National Laboratory	11,246	10,255	6,089
Princeton Plasma Physics Laboratory	655	523	200
Stanford Linear Accelerator Center	4,088	4,043	3,569
Laboratory Technology Research			
Ames Laboratory	483	20	0
Argonne National Laboratory	8,384	2,337	4,200
Brookhaven National Laboratory	7,623	2,168	4,200
Continuous Electron Beam Accelerator Facility	284	0	0
Fermi National Accelerator Laboratory	160	0	0
Idaho National Engineering Laboratory	410	0	0
Lawrence Berkeley National Laboratory	9,410	2,714	4,200
Lawrence Livermore National Laboratory	100	0	0
Oak Ridge National Laboratory	10,724	2,445	4,200
Pacific Northwest National Laboratory	7,855	2,942	4,200
Princeton Plasma Physics Laboratory	425	0	0
Stanford Linear Accelerator Center	353	0	0

	FY 1995	FY 1996	FY 1997
Advanced Energy Projects			
Ames Laboratory	296	310	0
Argonne National Laboratory	302	771	900
Brookhaven National Laboratory	(7)	0	0
Lawrence Berkeley National Laboratory	750	580	890
Lawrence Livermore National Laboratory	1,331	724	925
Los Alamos National Laboratory	503	485	865
National Renewable Energy Laboratory	1,362	1,150	1,000
Oak Ridge National Laboratory	0	300	930
Sandia National Laboratory	630	637	700
Related Capital Funding			
Ames Laboratory	$176	$0	$8
Argonne National Laboratory	210	0	0
Brookhaven National Laboratory	39	0	0
Lawrence Berkeley National Laboratory	506	450	3,580
Lawrence Livermore National Laboratory	1,426	4,749	0
Los Alamos National Laboratory	837	865	750
National Renewable Energy Laboratory	9	0	0
Oak Ridge National Laboratory	810	840	750
Sandia National Laboratory	200	45	0

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q42. Please elaborate on the joint Energy Research-Defense Programs DOE 2000 Initiative.

a. How much Energy Research funding is included for this Initiative? How much DP funding?

A42. The FY 1997 budget request includes $10 million in the Office of Energy Research Computational and Technology Research program. Our understanding is that Defense Programs also intends to commit $10 million to this initiative in FY 1997.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q42. Please elaborate on the joint Energy Research-Defense Programs DOE 2000 Initiative.

b. What is the outyear schedule for this initiative and what are the outyear budget implications?

A42. DOE 2000 is planned as a five-year program. It is a high priority for the Department; however, the outyear budgets are still under negotiation within the Department as to both overall level and source of funds.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q43. It appears that the new Computational and Technology Research program is set up to replicate work that was previously done in the Basic Energy Sciences (BES) program. For example, it includes the old BES Applied Mathematical Sciences program, the BES Advanced Energy Projects, and the Small Business Innovation Research program, which was administered by BES.

a. What is rationale for setting up another bureaucratic structure within OER?

A43. The Computational and Technology Research (CTR) program integrates similar programs, that had been dispersed, to achieve greater effectiveness. Its largest component, the previously-named Applied Mathematics subprogram, has been managed separately from the Basic Energy Sciences program since 1985 as a research program benefitting all of Energy Research. The Advanced Energy Projects subprogram funds radically new scientific ideas in fundamental research that no one else supports, or is interested in supporting in any field related to the Department of Energy's missions through a three-year research cycle, to determine their value for further development, which is quite different from usual Basic Energy Sciences practices. The Small Business Innovation Research program implements for all of DOE P.L. 97-219 and its reauthorization, P.L. 102-564.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q43. It appears that the new Computational and Technology Research program is set up to replicate work that was previously done in the Basic Energy Sciences (BES) program. For example, it includes the old BES Applied Mathematical Sciences program, the BES Advanced Energy Projects, and the Small Business Innovation Research program, which was administered by BES.

b. What additional cost is required for the new program?

A43. No additional cost is required to assemble the program. Each component directly continues previous appropriations. There has been no increase in FTE levels to support this program.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q44. Please provide a complete listing of all Laboratory Technology Research funded CRADA's including, for each, funding by fiscal year and out-year funding requirements to complete.

A44. I will be happy to provide that information in a table for the record.

The industrial partner for these projects brings matching contributions or better

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
ANL	Development of rapid prototype technology	Spectra Group Limited/ Scientific Measurement Systems	Maumee Austin	OH TX	280			
ANL	Studies of scaling processes and inhibition in industrial boiler and cooling water systems	NALCO Chemical Corp.	Naperville	IL	290			
ANL	Development of environmentally acceptable microbial corrosion control methods	The Gas Company	Los Angeles	CA	280			
ANL	Development of LUMELOID, a solar energy conversion material	Advanced Research Development, Inc.	Athel	MA	100	200		
ANL	Application of high performance computing to automotive design and. manufacturing	USCAR, Supercomputing Automotive Applications Partnership (SAA) and University of Michigan	Dearborn	MI	200	300		
ANL	Wear- and corrosion-resistant coatings for plastics exposed to alcohol fuel environments	GM AC Rochester Division	Flint	MI	240			
ANL	Cold cathode electron emmission from diamond-like carbon thin films for flat panel displays	SI Diamond Technology, Inc	Houston	TX	140	140		
ANL	Advanced nuclear power plant simulation	Fauske & Associates, Inc	Oak Brook	IL	100	200		
ANL	Bioremediation of contaminated soils by enhanced plant accumulation	Applied Natural Sciences, Inc	Hamilton	OH	200	300		
ANL	Giant magnetoresistance wire sensor	Segax Technology Corporation	Columbia Heights	MN	150	300	150	

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
ANL	Development of rapid prototyping technology for bioceramic applications	Zimmer, Inc, Knight & Packer, Inc, M&M Orthopaedics, Ltd	Warsaw	IN	136	376	376	
ANL	Experimental evaluation of atomizing nozzles of fluid catalytic cracking units	Amoco Research Center	Naperville	IL	250	250	250	
ANL	Oxygen-enriched technology for locomotives	Association of American Railroads	Washington	DC	150	300	150	
ANL	Development of a new generation petroleum reservoir simulator	University of Texas	Austin	TX	150	600	500	400
BNL	Microfabrication of a high aspect ratio micro-accelerometer auto crash sensor	Loral Control Systems	Archbald	PA	250	170	120	
BNL	Medical applications of Gadolinium- and/or boron-labeled pharmaceuticals	Boron Biologicals, Inc.	Raleigh	NC	90	110	150	
BNL	Composite metal-hydrogen electrodes for metal-hydrogen batteries	Energy Conversion Devices, Inc.	Troy	MI	115	110		
BNL	Development of CdTe/CdZnTe materials for radiation detectors	eV Products Division of II-IV, Inc.	Saxonburg	PA	115	75		
BNL	Corrosion resistance of new alloys for biomedical applications	Smith & Nephew Richards Inc.	Memphis	TN	25	140	20	
BNL	Condensing economizers for improved efficiency & reduced pollution	Consolidated Edison Company of New York and Babcock and Wilcox	New York	NY	20	275		
BNL	Regional high speed network	NYSERNET, Inc.	Liverpool	NY	122	100		

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
BNL	Biochemical production of absorbents from fossil fuel wastes	EER Labs, Inc.	Altadena	CA	35	65		
BNL	Sensor material and device characterization techniques using infrared pulses	Grumman Aerospace Inc.	Bethpage	NY	25	91		
BNL	Development of peptide-based radiopharmaceuticals, specific-construct approach	RhoMed Inc.	Albuquerque	NM	265	40		
BNL	In-situ reaction of insulating compounds	W. R. Grace	Columbia	MD	75	0		
BNL	Radiopharmaceutical for treatment of bone pain	Diatech, Inc	Londonderry	NH	190	255	65	
BNL	Biochemical processing of waste produced in energy production	CET Environmental Services, Inc	Emeryville	CA	17	100	83	
BNL	DNA repair enzyme-liposomes: human skin cancer prevention	Applied Genetics	Freeport	NY	170	252	82	
BNL	High beam current, low energy targetry for production of radioisotopes for positron emission	AccSys Technology, Inc	Pleasanton	CA	45	271	226	
BNL	Development of a 10-bit 500 Msample/sec waveform digitizer	LeCroy	Chestnut Ridge	NY	120	143		
BNL	Instrumentation for high throughput DNA sequencing	LI-COR, Inc	Lincoln	NE	60	222	162	
BNL	Development of an in-situ scanning surface profiler	Continental Optical	Hauppauge	NY	30	119	89	

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
BNL	Low temperature liquid phase catalytic synthesis of methanol from synthesis gas	Amoco Corporation	Naperville	IL	123	242	119	
BNL	Nondestructive x-ray scattering characterization of high temperature superconducting wires	Intermagnetics General Corp	Latham	NY	140	210	70	
BNL	Thin film lithium batteries	Power Conversion, Inc	Elmwood Park	NJ	90	148	56	
BNL	Production of non-toxic environmentally acceptable inhibitors for corrosion	W.R. Grace	Columbia	MD	160	192	32	
BNL	BNL citric acid technology: pilot scale demonstration	Forrester Environmental Services	Stratham	NH	75	148	71	
BNL	New catalysts for direct methanol oxidation fuel cells	International Fuel Cells	Windsor	CT	15	170	155	
BNL	Synchrotron computed microtomography: fluid rock studies	Mobil/GTE	Dallas Needham	TX MA	176	200	200	400
LBL	Develop protein to accelerate tendon & ligament repair	Amgen Corp.	Thousand Oaks	CA	111			
LBL	Neurochemical imaging of gene therapy	SOMATIX Therapy Corporation	Alameda	CA	357	357	20	
LBL	Novel materials for contact lenses	Vistakon	Jacksonville	FL	75	215	50	
LBL	Medical accelerator tech	General Atomics, Massachusetts General Hospital, and Loma Linda University Medical Center	San Diego	CA	126	364		

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
LBL	Rechargeable zinc/air batteries for consumer applications	Rayovac	Madison	WI	15	80		
LBL	Development of low NOx natural gas water heater	Teledyne Laars	Moorpark	CA	74	48		
LBL	Development of blue-emitting GaN LEDs and lasers	Hewlett-Packard Laboratories	Palo Alto	CA	100			
LBL	Cloning genes for diabetes	Rhone Poulenc-Rorer	Collegeville	PA	194	202		
LBL	Micromagnetic structures	IBM Research Center	San Jose	CA	71	350	79	
LBL	Development of zinc/nickel oxide batteries for vehicle applications	Energy Research Corporation	Danbury	CT	90	42		
LBL	Development and commercialization of a carbon monoxide occupational dosimeter	Quantum Group, Inc	San Diego	CA	100	85		
LBL	Amorphous diamond flat panel displays	SI Diamond Technology, Inc	Houston	TX	298			
LBL	Enzymatic remediation of waste streams	Enzymol International, Inc	Columbus	OH	75	119		
LBL	Catalytic conversion of chloro-fluorcarbons over palladium-carbon catalysts	DuPont Company	Wilmington	DE	104	250	122	
LBL	Prototype distributed health care imaging on the national information infrastructure	Kaiser Foundation	Oakland	CA	133	80		

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
LBL	Structure of erythropoietin receptor	Amgen, Inc	Thousand Oaks	CA	268	325		
LBL	Subsalt imaging with marine magnetotellurics	Scripps Institute of Oceanography	La Jolla	CA	139	325	300	300
LBL	Subsidence, analysis and control	Long Beach Dept of Oil Prop	Long Beach	CA	108	200	200	300
LBL	Optimal fluid injection policy and producibility in fractured, low permeability reservoirs	Cal resource Ltd, Mobil, Crutcher Tufts, Unocal	Bakersfield	CA	118	200	200	300
LBL	Advanced flux visualization and virtual reality for reservoir engineering	BP, Western Atlas	Houston	TX	99	200	200	300
LBL	Advanced computational analysis of drill cuttings for real time well site decisions	ARCO, E&P Technology, BP-America	Houston	TX	498	400	300	300
LBL	Development of high-resolution subsurface electromagnetic imaging tool for process monitoring and	Atlas Wireline Services	Houston	TX	215	300	300	300
ORNL	Alloy design of Nd2Fe14b permanent magnets	General Motors, Magnequench Div.	Anderson	IN	282	150	50	
ORNL	Electronic device application of rechargeable thin film lithium batteries	Research International	Woodinville	WA	70	100		
ORNL	Development of aluminum bridge deck system	Reynolds Metals Co	Richmond	VA	100	100	100	
ORNL	Advanced quadrupole ion trap instrumentation for low level vehicle emissions measurements	Environmental Research Consortium of USCAR	Dearborn	MI	50	235		

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
ORNL	Ion implantation processing technologies	AT&T	Murray Hill	NJ	100	100		
ORNL	Development of environmentally conscious machining fluids and systems	Cincinnati Milicron	Cincinnati	OH	446	250		
ORNL	Rapid prototyping of ceramics	Allied Signal and 3D	Valencia	CA	575	150	150	400
ORNL	Novel methods for fabrication cost reduction of pressure infiltration cast metal matrix composite components	Metal Matrix Composite Castings	Waltham	MA	200	225	75	
ORNL	Identification of genes affecting the immune system	Darwin Molecular Corp	Bothell	WA	70	230	150	400
ORNL	In-line aluminum sensors	Kaiser, Alumax, Reynolds	Ferndale	WA	70	90	110	
ORNL	Manufacturing of nibase superalloys with improved high-temp performance	Allvac/Teledyne	Monroe	NC	150	100	100	
ORNL	Moving advanced desiccant materials into mainstream non-CFC cooling products	Engelhardt/ICC	Philadelphia	PA	50	125	245	
ORNL	Role of Yttrium in improving oxidation resistaance in superalloys for turbine applications	Pratt and Whitney	East Hartford	CT	45	105	60	
ORNL	Ultra precise automated measurement for manfacturing	Interscience	Troy	NY	80			
ORNL	Air conditioning system with improved efficiency for hybrid/electric vehicles	Narton Corp	Reed City	MI	200	130	110	

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
ORNL	New thermoelectric materials for solid state refrigeration	Marlow Industries	Dallas	TX	180	155	125	
ORNL	Thin film battery powered transdermal medical device	Teledyne Electronic Technologies	Los Angeles	CA	160	100	140	
ORNL	Rapid prototyping of bioceramics for implants	Advanced Ceramics Research, Inc	Tucson	AZ	105	100	125	
ORNL	Textile Enabling Agile Manufacturing	Lear	Johnson City	TN	150	225	225	400
ORNL	Implantable drill bit monitor (ACTI)	Hughes Christensen	Woodlands	TX	102	220	300	300
ORNL	Testing advanced computational tools for 3D seismic analysis	SEG	Tulsa	OK	200	300	120	400
PNL	Metal matrix composites (MMC) for automotive gear applications	General Motors Gear Center	Romulus	MI	80	160		
PNL	Polymer multilayer (PML) film applications in optics, electrolytes, and glazings	Du Pont Advanced Glazing Venture, United Solar Technologies, Inc., Sigma Labs and University of	Wilmington Olympia Tucson	DE WA AZ	65	180		
PNL	Development of hybrid quantum mechanical/molecular mechanical methods	DuPont	Wilmington	DE	148	50		
PNL	Instrumentation for high speed analysis of vehicle emissions	Environmental Research Consortium of USCAR	Dearborn	MI	330			
PNL	High sensitivity electrospray ion source development	Finnigan MAT	San Jose	CA	145			

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
PNL	Development of near-field optical microscope and spectrometer	Digital Instruments, Inc. and University of Chicago	Santa Barbara	CA	145			
PNL	Development of mixed metal oxides	Chemetals	Baltimore	MD	25	50		
PNL	Superplastic forming modeling and simulation	GM Corp. R&D Center, Univ. of Michigan and Wash. State Univ.	Warren	MI	340	160		
PNL	Tape calendering for air separation membranes	Air Prodicts	Allentown	PA	40	200		
PNL	Multilayer thermal barrier coatings for gas turbine	Westinghouse, Allied Signal, Ohio State, EPRI, Solar Turbines & Howmet	San Diego	CA	275	300		
PNL	Reinforced castings for reduced emissions	USCAR-LEP, GM	Dearborn	MI	181	100		
PNL	Photocatalytic destruction of auto exhaust emissions	USCAR-LEP, Ford	Dearborn	MI	170	400		
PNL	Supercritical fluid extraction for pesticide residue analysis	DuPont	Wilmington	DE	25	300		
PNL	Bioactive and porous metal coatings for improved tissue regeneration	Health Tech Development	Dallas	TX	155	265		
PNL	Solid acid environmental catalysis	Catalytica, Inc	Mt. View	CA	15	40		

Laboratory	Project Title	Partner	City	State	FY 96	FY 97	FY 98	FY 99
PNL	Inductively coupled plasma-ion trap mass spec	Finnigan Corp	San Jose	CA	135	30		
Multiple Labs	Demand-Activated Manufacturing Architecture	Textile/Clothing Technology Corp.	Cary	NC	1,344			
Multiple Labs	Computer-Aided Fabric Evaluation	Institute for Textile Technology	Charlottesville	VA	86			
Multiple Labs	Textile Resource Conservation	Institute for Textile Technology	Charlottesville	VA	391			
Multiple Labs	Cotton Biotechnology	Cotton, Inc.	New York	NY	100			
Multiple Labs	On-Line Process Control Automation	Textile Research Institute	Princeton	NJ	100			
TOTAL					14,241	16,381	7,032	4,500

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q45. One of the FY 1997 planned accomplishments for Mathematical, Information, and Computational Sciences says that "Funding in the amount of $2,957,000 has been budgeted for the SBIR program" (FY *1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, pg. 326). However, the narrative also states that $2,044,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (44.7 percent) for SBIR?

A45. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P.L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from (1) this legal requirement, and (2) an increase in the FY 1997 request due to a transfer of funds from the Office of Fusion Energy to support the supercomputer access program ($7,600,000) and funding for the DOE 2000 initiative ($5,000,000).

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q46. One of the FY 1997 planned accomplishments for Laboratory Technology Research says that "Funding in the amount of $545,00 has been budgeted for the SBIR program" (FY 1997 *Congressional Budget Request:* *Energy Supply Research and Development,* DOE/CR-0035, Volume 2 of 5, p. 329). However, the narrative also states that $306,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (78.1 percent) for SBIR?

A46. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P.L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from (1) this legal requirement, and (2) an increase of $4,130,000 in the FY 1997 request for the Laboratory Technology Research program.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Computational and Technology Research (CTR)

Q47. One of the FY 1997 planned accomplishments for Advanced Energy Projects says that "Funding in the amount of $287,000 has been budgeted for the SBIR program. (*FY 1997 Congressional Budget Request: Energy Supply and Development,* DOE/CR-0035, Volume 2 of 5, p. 332). However, the narrative also states that $224,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (28.1 percent) for SBIR?

A47. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM SENATOR ROHRABACHER

University and Science Education (USE)

Q48. Please provide the level of funding for each DOE Laboratory for each USE Program Activity (i.e., Laboratory Cooperative Program, and University Programs Operating Expenses) for each of FY 1995, FY 1996 and 1997.

A48: I will be happy to provide that information in a table for the record.

University Science Education
Laboratory Cooperative Program
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Ames Laboratory	$ 428	$ 95	$ 100
Argonne National Laboratory	4,993	2,105	2,700
BDM Corporation - Oklahoma	162	0	0
Brookhaven National Laboratory	1,896	695	900
Continuous Electron Beam Acc. Facility	593	100	150
EG&G Mound App. Technology	100	25	0
Fermi National Accelerator Laboratory	1,257	355	350
Fernald Env. Res. Mgmt. Corp.	53	0	0
Idaho National Engineering Laboratory	175	120	150
Inhalation Toxicology Research Institute	90	20	0
Lawrence Berkeley National Laboratory	2,136	825	1,050
Lawrence Livermore National Laboratory	1,548	395	500
Los Alamos National Laboratory	1,474	440	500
National Renewable Energy Laboratory	261	50	50
Oak Ridge National Laboratory	1,220	637	700
Pacific Northwest National Laboratory	1,287	380	450
Princeton Plasma Physics Laboratory	381	300	300
Sandia National Laboratory	747	375	400
Savannah River Ecology Lab	149	100	100
Savannah River Tech. Center	95	5	0
Stanford Linear Accelerator Center	183	80	100
Associated Western Universities*	5,194	2,170	2,000
Oak Ridge Institute for Science & Education*	1,803	2,857	2,975

* Funding is targeted to support undergraduate/graduate student and faculty research participants at DOE National Laboratories

University Science Education
University Programs
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	$ 295	$ 150	$ 0
Brookhaven National Laboratory	167	0	0
Lawrence Berkeley National Laboratory**	833	0	100
Oak Ridge National Laboratory**	200	100	100
Pacific Northwest National Laboratory	124	0	0
Sandia National Laboratory**	740	900	900
Oak Ridge Institute for Science & Education*	4,701	1,100	725

* Funding is targeted to support undergraduate/graduate students and faculty participating in research at DOE National Laboratories

** Funding is used to support undergraduate/graduate student and faculty from HBCUs and other minority institutions belonging to DOE Lab consortia and alliances for research participation opportunities at the DOE National Labs.

QUESTION FROM REPRESENTATIVE ROHRABACHER

University and Science Education (USE)

Q49. One of the FY 1997 planned accomplishments for USE says that "Funding in the amount of $498,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p. 314). However, the narrative also states that $368,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (35.3 percent) for SBIR?

A49. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM REPRESENTATIVE ROHRABACHER

University and Science Education (USE)

Q50. One of the FY 1997 planned accomplishments for USE says that "Funding in the amount of $498,000 has been budgeted for the SBIR program" (*FY 1997 Congressional Budget Request: Energy Supply Research and Development*, DOE/CR-0035, Volume 2 of 5, p. 314). However, the narrative also states that $368,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (35.3 percent) for SBIR?

A50. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

QUESTION FROM REPRESENTATIVE ROHRABACHER

High Energy (HEP)

Q51: What is the status of the U.S.' formal negotiation of its involvement in the CERN Large Hadron Collider (LHC) project, and when is the negotiation expected to be completed?

A51: In March of 1996, the Department of Energy and CERN agreed on a level of Department of Energy contribution to the Large Hadron Collider (LHC) accelerator, and a level of contribution from the Department of Energy and the National Science Foundation (NSF) to the two large detectors, as the basis for negotiations. It is anticipated that most if not all of these contributions will be in the form of goods and services purchased in the United States. The Department of Energy, the National Science Foundation and CERN have formed a Negotiating Team, co-chaired by the Director of the Office of Energy Research and the Director General of CERN, and three subordinate working groups. The working groups have made good progress. The Negotiating Team met on June 24-25 at CERN. If the negotiations continue at their current pace, they will be concluded by the end of the year. The actual signing of an agreement may be somewhat later.

QUESTION FROM REPRESENTATIVE ROHRABACHER

High Energy (HEP)

Q52. Please provide the funding, by institution, for U S participation in the LHC for each of FY 1995, FY 1996, and FY 1997, including a brief description of the work performed by each funded institution.

A52. The funding and a brief technical description, by institution, for U.S. participation in LHC for FY 1996 is provided in a table for the record. In FY 1997, work will continue in many of the same technical areas, but specific funding levels have not been determined pending the completion of detailed planning and discussions within the collaborations and with CERN. A total of $15 million has been requested for FY 1997.

Institution	FY 1995 ($000)	FY 1996 ($000)	R&D on
ANL		$ 190	Tile calorimeter and trigger system for ATLAS.
BNL		$ 827	Liquid calorimeter and muon detector system for ATLAS and conversion of cable test facility for 1.8 degree Kelvin operation
Fermilab		$ 806	The muon endcaps, the hadron calorimetry, the trigger and data acquisition, and the charged particle tracking subsystem for the CMS, and on the insertion region superconducting quadrupole magnets.
LANL	$ 75		CMS design.
LBNL		$ 432	Silicon detectors for ATLAS the beam tube vacuum subsystem, and the insertion region super-conducting quadrupole magnets.
Arizona, Univ. of	$ 80	$ 128	Forward calorimetry, the muon system, endcap integration.
Boston Univ.	$ 68	$ 139	Muon spectrometer, front-end electronics, interface to ATLAS trigger and DAQ system.

Brandeis Univ.	$ 50	$ 71	Drift tubes for ATLAS.
Caltech	$ 30	$ 60	Lead tungstate crystal electomagnetic calorimeter.
Carnegie Mellon Univ.		$ 72	Endcap chamber front-end readout electronics
Univ. of Calif., Davis	$ 40	$ 208	Switched capacitor array electronic chip, software and computing development, and components of central tracking system.
Univ. of Calif., Irvine	$ 42	$ 63	Readout and control electronics for tests of pixel and silicon strip detectors and development of trigger and DAQ.
Univ. of Calif., Riverside	$ 15	$ 72	Endcap muon system prototypes for CMS.
Univ. of Calif., Santa Cruz	$ 42	$ 184	Front-end electronics for ATLAS Semiconductor Tracker.
Univ. of Calif., San Diego		$ 83	Trigger and data acquisition of CMS detector.
Univ. of Calif., LA	$ 15	$ 135	The Compact Muon Spectrometer.
Duke Univ.	$ 40	$ 65	Transition Radiation Tracker prototype.
Fairfield Univ.		$ 29	Quartz fiber very forward calorimeter subsystem of CMS.
Florida, Univ. of		$ 21	Cathode strip chambers for the endcap muon system of the CMS detector.
Florida St. Univ.	$ 20	$ 37	Hadronic calorimeter for CMS.
Harvard Univ.		$ 74	Front-end electronics for the Monitored Drift Tubes.
Illinois, Univ. of	$ 48	$ 63	ATLAS hadron calorimeter.
Indiana Univ.	$ 40	$ 89	Transition Radiation Tracker for the ATLAS detector.
Iowa, Univ. of	$ 20	$ 89	Very-forward calorimeter and hadron barrel calorimeter for CMS.
Maryland, Univ. of	$ 72	$ 120	Hadron calorimeter, and scintilator trays for barrel and endcap.

Minnesota, Univ. of	$ 10	$ 205	The Compact Muon Spectrometer.
Mississippi, Univ. of		$ 89	Hadron calorimeter, tracking, and trigger/DAQ subsystems of the CMS detector
MIT	$ 60	$ 83	Muon chamber for ATLAS, and DAQ and trigger subsystems for CMS.
Northwestern Univ.		$ 32	The Compact Muon Spectrometer.
Ohio St. Univ.	$ 35	$ 121	The Compact Muon Spectrometer
Penn., Univ. of	$ 48	$ 119	ATLAS detector.
Pittsburgh, Univ. of	$ 35	$ 30	Calorimeter readout chain and signal processing for the ATLAS detector
Princeton Univ.	$ 46	$ 110	Electron magnetic calorimeter.
Purdue Univ.		$ 97	HCAL project, cathode strip muon chambers.
Rice Univ.		$ 5	Tracking subsystem of CMS.
Rochester, Univ. of	$ 80	$ 42	Liquid calorimetry subsystem for ATLAS
SUNY SB		$ 6	The Compact Muon Spectrometer.
Texas Tech		$ 15	Quartz fiber very forward calorimeter subsystem of CMS.
Tufts Univ.		$ 29	Monitored drift tubes for ATLAS
Univ. of Texas, Arl.	$ 20	$ 70	Tile calorimeter for ATLAS.
Wisconsin, Univ. of	$ 92	$ 339	Readout and control electronics for tests of pixel detector and electronics for ATLAS.

QUESTION FROM REPRESENTATIVE ROHRABACHER

High Energy (HEP)

Q53. One of the FY 1997 planned accomplishments for HEP Facilities Operations says that "Funding in the amount of $7,945,000 has been budgeted for the SBIR program" *(FY 1997 Congressional Budget Request:* *General Science and Research, etc.* , DOE/CR-0035, Volume 3 of 5, p. 29). However, the narrative also states that $4,598.000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (66.3 percent) for SBIR?

A53. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

Funding for the SBIR program is contained in both the Facilities Operations and the High Energy Technology subprograms. The total funding for SBIR was $9,530,000 in FY 1996 and $12,185,000 in FY 1997.

QUESTION FROM REPRESENTATIVE ROHRABACHER

High Energy (HEP)

Q54. Please describe the scope and purpose of the Next Linear Collider Test Facility (NLCTF) at the Stanford Linear Accelerator Center (SLAC).

A54. The central purpose of the Next Linear Collider Test Accelerator (NLCTA) at SLAC is to provide a full scale test bed for RF power sources, high gradient beam accelerating structures, and beam control and diagnostic systems. This is an essential next step in the international collaborative R&D program at SLAC looking toward a possible high energy linear collider. The principal component is a 50 MeV electron linac including klystrons, modulators, and the accelerating structure, but the project also provides the beam injection system, power supplies, water cooling, and safety systems.

QUESTION FROM REPRESENTATIVE ROHRABACHER

High Energy (HEP)

Q55. One of the FY 1997 planned accomplishments for HEP High Energy Technology says that "Funding in the amount of $4,231,000 has been budgeted for the SBIR program: (*FY 1997 Congressional Budget Request:* *General Science and Research, etc.*, DOE/CR-0035, Volume 3 of 5, p.34). However, the narrative also states that $4,932,000 has been budgeted for SBIR in FY 1996. Why is there such a large decrease (16.6 percent) for SBIR?

A55. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement.

Funding for the SBIR program is contained in both the Facilities Operations and the High Energy Technology subprograms. The total funding for SBIR was $9,530,000 in FY 1996 and $12,185,000 in FY 1997.

QUESTION FROM REPRESENTATIVE ROHRABACHER

High Energy (HEP)

Q56. The FY 1997 request for High Energy Physics Capital Equipment continues the past practice of funding expensive detectors (e.g., $55.2 million total estimated cost for the D-Zero Upgrade, $57.94 million total estimated cost for the CDF Upgrade, and $67.0 million for the B-Factory detector). Why is this? Why are large, expensive HEP detector projects not considered to be construction projects and not subjected to the discipline of the DOE construction project process?

A56. The high energy physics detectors (such as the B-factory detector) and major detector upgrades (such as the CDF and D-Zero Upgrades) consist entirely of technical components installed in existing facilities. These components are not permanently fixed in place. Thus, in accord with long standing DOE budget and accounting guidelines detectors have been funded as capital equipment projects. While not subject to the full DOE project control system, the major high energy physics detector projects are subjected to regular cost, scope and schedule reviews by the Construction Management Support Division, within the Office of Energy Research.

QUESTION FROM REPRESENTATIVE ROHRABACHER

High Energy (HEP)

Q57. Please provide the outyear funding requirements for the following detector projects: (a) D-Zero Upgrade, (b) CDF Upgrade, and (c) B-Factory detector (BaBar).

A57. I will be happy to provide that information in a table for the record.

Outyear Funding Requirements
(B/A in thousands)

	FY 1997 Pres Req	FY 1998 Est	FY 1999 Est
D-Zero Upgrade	$10,000	$15,500	$9,208
CDF Upgrade	10,000	15,500	10,408
BaBar	20,500	17,000	7,000

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q58. Please provide the level of funding for each DOE Laboratory for Medium Energy Nuclear Physics for each of FY 1995, FY 1996 and 1997.

A58. I will be happy to provide that information in a table for the record.

Nuclear Physics
Medium Energy Nuclear Physics
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	3,068	3,060	3,060
Brookhaven National Laboratory	2,358	2,370	2,370
Thomas Jefferson National Accelerator Facility/CEBAF	57,066	56,300	60,490
Lawrence Livermore National Laboratory	50	0	0
Los Alamos National Laboratory	36,265	7,857	6,675[a]
Bates Linear Accelerator Center (MIT)[b]	13,671	14,118	14,818

[a] Current program estimate for Los Alamos National Laboratory has been revised to $7,800,000.

[b] Bates Linear Accelerator Center is being managed under Cooperative Agreement No. DE-FC02-94ER40818 with the Massachusetts Institute of Technology.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q59. One of the FY 1997 planned accomplishments for Medium Energy Nuclear Physics says that "Funding in the amount of $4,073,000 has been budgeted for the SBIR program" (FY 1997 *Congressional Budget Request: General Science and Research, etc.*, DOE/CR-0035, Volume 3 of 5, p. 77). However, the narrative also states that $1,965,000 has been budgeted for SBIR in FY 1996. Why is there such a large increase (197.3 percent) for SBIR?

A59. SBIR allocations for three subprograms for FY 1996 and FY 1997 within Nuclear Physics are as follows:

	(B/A in thousands)	
	FY 1996	FY 1997
Medium Energy Nuclear Physics	1,965	4,073
Heavy Ion Nuclear Physics	945	520
Low Energy Nuclear Physics	1,200	850
Total	4,110	5,443
Reprogramming Action	26	
Reprogramming Total	4,136[a]	

The 32% increase in the total amount for SBIR is due to the 25% increase in the SBIR taxation rate and to an increased amount of Nuclear Physics funding assigned to the operating category. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement. In preparation of the budget the SBIR total amount is set aside, while the remaining funding allocation is distributed for maximum program effectiveness.

[a] The current estimate for SBIR in FY 1996 is $4,136,000. The increase results from approval of the recent reprogramming action for the Thomas Jefferson National Accelerator Facility/CEBAF.

This distribution is guided by the scientific priorities developed by the DOE/NSF Nuclear Science Advisory Committee in "Nuclear Science: A Long Range Plan" and by results of the peer review process for scientific merit. Subsequently, the SBIR amount was arbitrarily divided between subprograms; the distribution between subprograms has no significance

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q60. Please provide the level of funding for each DOE Laboratory for Heavy Ion Nuclear Physics for each of FY 1995, FY 1996 and 1997.

A60. I will be happy to provide that information in a table for the record.

Nuclear Physics
Heavy Ion Nuclear Physics
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	9,590	9,866	10,005
Brookhaven National Laboratory	17,992	21,785	24,185
Lawrence Berkeley National Laboratory	14,770	14,785	14,865
Lawrence Livermore National Laboratory	315	290	295
Los Alamos National Laboratory	1,035	1,115	1,125
Oak Ridge National Laboratory	2,260	2,340	2,365
Bates Linear Accelerator Center (MIT)[a/]	0	0	0

[a/] Bates Linear Accelerator Center is being managed under Cooperative Agreement No. DE-FC02-94ER40818 with the Massachusetts Institute of Technology

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q61. One of the FY 1997 planned accomplishments for Heavy Ion Nuclear Physics Relativistic Heavy Ion Studies says that "Funding in the amount of $520,000 has been budgeted for the SBIR program" (FY 1997 *Congressional Budget Request: General Science and Research, etc.*, DOE/CR-0035, Volume 3 of 5, p. 83) However, the narrative also states that $945,000 has been budgeted for SBIR in FY 1996. Why is there such a large decrease (81.2 percent) for SBIR?

A61. SBIR allocations for three subprograms for FY 1996 and FY 1997 within Nuclear Physics are as follows:

	(B/A in thousands)	
	FY 1996	FY 1997
Medium Energy Nuclear Physics	1,965	4,073
Heavy Ion Nuclear Physics	945	520
Low Energy Nuclear Physics	1,200	850
Total	4,110	5,443
Reprogramming Action	26	
Reprogramming Total	4,136[a]	

The 32% increase in the total amount for SBIR is due to the 25% increase in the SBIR taxation rate and to an increased amount of Nuclear Physics funding assigned to the operating category. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement. In preparation of the budget the SBIR total amount is set aside, while the remaining funding allocation is distributed for maximum program effectiveness.

[a] The current estimate for SBIR in FY 1996 is $4,136,000. The increase results from approval of the recent reprogramming action for the Thomas Jefferson National

Accelerator Facility/CEBAF.
This distribution is guided by the scientific priorities developed by the DOE/NSF Nuclear Science Advisory Committee in "Nuclear Science: A Long Range Plan" and by results of the peer review process for scientific merit. Subsequently, the SBIR amount was arbitrarily divided between subprograms; the distribution between subprograms has no significance.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q62. Please provide the level of funding for each DOE Laboratory for Low Energy Nuclear Physics for each of FY 1995, FY 1996 and 1997.

A62. I will be happy to provide that information in a table for the record.

Nuclear Physics
Low Energy Nuclear Physics
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	215	275	335
Brookhaven National Laboratory	3,050	2,400	2,800
Idaho National Engineering Laboratory	0	0	100
Lawrence Berkeley National Laboratory	1,760	1,445	1,700
Lawrence Livermore National Laboratory	307	325	400
Los Alamos National Laboratory	830	1,450	1,450
Oak Ridge National Laboratory	7,709	8,150	9,200
Bates Linear Accelerator Center (MIT)[a]	0	0	0

[a] Bates Linear Accelerator Center is being managed under Cooperative Agreement No DE-FC02-94ER40818 with the Massachusetts Institute of Technology.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q63. One of the FY 1997 planned accomplishments for Low Energy Nuclear Physics Structure of Nuclei says that "Funding in the amount of $850,000 has been budgeted for the SBIR program" (FY 1997 *Congressional Budget Request: General Science and Research, etc.*, DOE/CR-0035, Volume 3 of 5, p 89). However, the narrative also states that $1,200,000 has been budgeted for SBIR in FY 1996. Why is there such a large decrease (29.2 percent) for SBIR?

A63 SBIR allocations for three subprograms for FY 1996 and FY 1997 within Nuclear Physics are as follows.

	(B/A in thousands)	
	FY 1996	FY 1997
Medium Energy Nuclear Physics	1,965	4,073
Heavy Ion Nuclear Physics	945	520
Low Energy Nuclear Physics	1,200	850
Total	4,110	5,443
Reprogramming Action	26	
Reprogramming Total	4,136[a]	

The 32% increase in the total amount for SBIR is due to the 25% increase in the SBIR taxation rate and to an increased amount of Nuclear Physics funding assigned to the operating category. The SBIR program was extended in October 1992, to the year 2000 by the Small Business Research and Development Enhancement Act of 1992, P. L. 102-564. That legislation called for the SBIR set aside to increase from 2.0 percent of the Department's extramural R&D budget in FY 1996 to 2.5 percent in FY 1997. The amount budgeted for SBIR in FY 1997 was determined from this legal requirement. In preparation of the budget the SBIR total amount is set aside, while the remaining funding allocation is distributed for maximum program effectiveness.

[a] The current estimate for SBIR in FY 1996 is $4,136,000. The increase results from approval of the recent reprogramming action for the Thomas Jefferson National Accelerator Facility/CEBAF.

This distribution is guided by the scientific priorities developed by the DOE/NSF Nuclear Science Advisory Committee in "Nuclear Science: A Long Range Plan" and by results of the peer review process for scientific merit. Subsequently, the SBIR amount was arbitrarily divided between subprograms; the distribution between subprograms has no significance.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q64 Please provide the level of funding for each DOE Laboratory for Nuclear Theory for each of FY 1995, FY 1996 and 1997

A64. I will be happy to provide that information in a table for the record.

Nuclear Physics
Nuclear Theory
(B/A in thousands)

	FY 1995	FY 1996	FY 1997
Argonne National Laboratory	$ 900	$ 900	$ 920
Brookhaven National Laboratory	1,176	1,065	1,120
Thomas Jefferson National Accelerator Facility/CEBAF	492	500	510
Lawrence Berkeley National Laboratory	850	910	930
Lawrence Livermore National Laboratory	90	0	0
Los Alamos National Laboratory	850	850	930
Oak Ridge National Laboratory	590	750	820
Bates Linear Accelerator Center (MIT)[a]	0	0	0

[a] Bates Linear Accelerator Center is being managed under Cooperative Agreement No. DE-FC02-94ER40818 with the Massachusetts Institute of Technology.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q65. Please provide the outyear funding requirements for the following detector projects: (1) Silicon Vertex Tracker and (b) Muon Arm Instrumentation.

A65. I will be happy to provide that information in a table for the record.

Outyear Requirements
(B/A in thousands)

	TEC	Previous Approp.	FY 1997 Request	Estimated Outyears Required
Silicon Vertex Detector	$ 6,000	$ 1,550	$ 2,000	$ 2,450
Muon Arm Instrumentation	$11,400	$ 800	$ 2,650	$ 7,950

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q66. FY 1997 *Congressional Budget Request* General Science and Research, etc., DOE/CR-0035, Volume 3 of 5, p. 106 states: "The FY 1996 Congressional Appropriation reduced construction funding from $70 million to $65 million. This reduction was partially offset by an additional $2.5 million in operating and $1 million in capital equipment funding. These funding actions result in a 3 month delay in the project completion date from the second quarter of FY 1999 to the third quarter of FY 1999 and increase the TEC and TPC. The TEC has increased from $475,250,000 to $486,870,000. The TPC has increased from $595,250,000 to $616,530,000. The increase in cost covers the support of core personnel essential for subsequent operations, stretch-out costs associated with revised work schedules to accommodate the funding profile, and escalation on the FY 1996 reduction, which is to be restored in FY 1999."

a. Please explain in detail how a net reduction $1.5 million in RHIC funding in FY 1996 results in an increase of $11.62 million in RHIC's TEC and an increase of $21.28 million in RHIC's TPC.

A66. Inherent in the previous project baseline of RHIC was a significant amount of schedule risk. This risk was due to a reduced annual funding profile introduced in Fiscal Year 1994 by the Nuclear Physics program because of reduced overall funding. At that time, major industrial contracts for superconducting magnets were in place which had been negotiated under the assumption of the original funding profile. Following advice of a technical review committee, it was decided to honor those existing industrial contracts in order to avoid the major cost increases of renegotiated contracts. The resulting cash flow problem was addressed by rescheduling the allocation of project contingency until late into the project. The baseline based on this strategy, however, did not provide flexibility for further annual reductions without significant increases in costs and schedule. The loss in buying power, resulting from the $5,000,000 reduction in construction funding in Fiscal Year 1996, is not restored until Fiscal Year 1999 when the project is scheduled to be completed. The RHIC core technical team which is now engaged in completing the construction project and commissioning the facility must be maintained until the facility becomes operational. The cash flow problem in Fiscal Year 1996 was partially off-set by the addition of $2,500,000 in operating and $1,000,000 in capital equipment funding. This funding was critical in efforts to mitigate the schedule impact from reduced construction funding by permitting special process spares to be purchased in conjunction with construction purchases and by enabling the experimental detector collaborations to maintain a viable schedule for the start of the RHIC physics program in 1999. Nevertheless, these additional funds could not totally compensate for the reduction of $5,000,000 in Construction funding, and a delay in project completion of 3 months could not be avoided.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q66. FY 1997 *Congressional Budget Request* General Science and Research, etc., DOE/CR-0035, Volume 3 of 5, p. 106 states: "The FY 1996 Congressional Appropriation reduced construction funding from $70 million to $65 million. This reduction was partially offset by an additional $2.5 million in operating and $1 million in capital equipment funding. These funding actions result in a 3 month delay in the project completion date from the second quarter of FY 1999 to the third quarter of FY 1999 and increase the TEC and TPC. The TEC has increased from $475,250,000 to $486,870,000. The TPC has increased from $595,250,000 to $616,530,000. The increase in cost covers the support of core personnel essential for subsequent operations, stretch-out costs associated with revised work schedules to accommodate the funding profile, and escalation on the FY 1996 reduction, which is to be restored in FY 1999."

b. Please detail the items which result in the TEC increase of $11.62 million and TPC increase of $21.28 million.

A66. The increases in the RHIC TEC and TPC arise from the need to support core project personnel over the three-month delay, labor cost increases due to stretching out production and assembly schedules, material increases due to less efficient procurement, and escalation on budget authority deferred until Fiscal Year 1999. The $21.28 million increase in the TPC results from a $11.62 million increase to the TEC for construction and a $9.66 million increase in Other Project Costs.

The construction increase of $11.62 million is detailed as follows:

Labor and associated direct cost to support the three-month delay as well as the effort associated with stretched-out production and assembly schedules -- $7.6 million.

Contingency to cover the risk associated with the delay in project completion -- $2.0 million ($1.5 million for the collider and $0.5 million for the detectors).

Materials cost increases to cover delayed and phased procurements predominantly for the detector efforts to cover electronics, some magnet components, and cooling water installations -- $1.4 million.

Escalation associated with the $5 million deferral of budget authority for Construction from fiscal year 1996 to fiscal year 1999 -- $0.62 million.

Other Project Costs increased by $9.66 million. Most of the increase is needed to support 140 staff positions for additional three-months ($7.0 million). These personnel, together with the remaining construction staff, comprise the core personnel necessary for RHIC operations. Electric power costs increased to cover extended operations of the cryogenic refrigeration plant needed to cool the superconducting magnets during commissioning are $2.3 million. The balance of $0.36 million covers direct costs associated with the extended commissioning schedule.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Nuclear Energy (NP)

Q66. FY 1997 *Congressional Budget Request* General Science and Research, etc., DOE/CR-0035, Volume 3 of 5, p. 106 states: "The FY 1996 Congressional Appropriation reduced construction funding from $70 million to $65 million. This reduction was partially offset by an additional $2.5 million in operating and $1 million in capital equipment funding. These funding actions result in a 3 month delay in the project completion date from the second quarter of FY 1999 to the third quarter of FY 1999 and increase the TEC and TPC. The TEC has increased from $475,250,000 to $486,870,000. The TPC has increased from $595,250,000 to $616,530,000. The increase in cost covers the support of core personnel essential for subsequent operations, stretch-out costs associated with revised work schedules to accommodate the funding profile, and escalation on the FY 1996 reduction, which is to be restored in FY 1999."

c. A comparison of the FY 1996 RHIC Construction Project Data Sheet and the FY 1997 RHIC Construction Project Data Sheet shows that collider installation costs increased by $5.39 million-from $25.83 million to $31.12 million, magnet system costs increased by $16.18 million-from $125.06 million to $141.24 million, and detector costs increased by $3 million-from $112.0 million to $115.0 million. Please provide the details of these cost increases.

A66. After the FY 1996 Congressional Budget was submitted the project costs were reviewed and the cost estimate was rebaselined as part of normal management procedures. Although the project total was not changed, adjustments were made between various project cost elements and portions of the contingency were allocated to specific project cost elements. The table below summarizes these changes. The collider installation, which is now 50% complete, increased by $5.29 million due almost exclusively to the additional scope of fabricating the interconnecting cryostats ($5.0 million). There was no additional increase to collider installation due to the fiscal 1996 funding reduction. The total cost of the magnet system, now 93 percent complete, increased by $12.86 million allocated from contingency to address actual costs of superconducting magnet contracts with industry, including over $12 million in cost growth for the Northrop Grumman Phase I (Technology Transfer) contract. These changes were reviewed and approved by the DOE project manager. I will be happy to provide this information in a table for the record.

Subsequently, the FY 1996 funding for the project was reduced by $5.0 million in construction. The table also delineates the changes between this rebaselined estimate and the revised estimate based on FY 1996 reduced funding. These cost increases result from the deferral of purchasing power for construction activities from FY 1996 to FY 1999 and three-month delay in project schedule. In particular, as result of the FY 1996 reduced funding, the magnet system cost increased by $3.32 million. The detectors, which are now nearly 50% complete, increased by $3.0 million due to the three-month delay in completion; construction labor ($1.5 million), material procurement cost ($1.0 million) and contingency ($0.5 million). These changes are described in the answer to question 66b above.

RHIC
(B/A in thousands)

Construction Costs	FY 1996 Data Sheet	FY 1996 Rebaseline	FY 1997 Data Sheet	Combined Changes
Engineering, Design, Inspection & Administration	77,660	82,333	83,982	6,322
Conventional Const.	9,730	9,730	9,640	(90)
Collider Installation	25,830	31,130	31,120	5,290
Magnet System	125,060	137,920	141,240	16,180
Collider Systems	98,240	95,670	97,920	(320)
Collider Contingency	26,730	6,467	7,968	(18,762)
	363,250	363,250	371,870	8,620
Detectors	112,000	112,000	115,000	3,000
	475,250	475,250	486,870	11,620
Other Project Costs	120,000	120,000	129,660	9,660
Total Project Cost	595,250	595,250	616,530	21,280

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards - Fiscal Year 1993

Q67. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC02-93ER40758) of $1,250,000 was made by the Director of Energy Research to the Walcoff & Associates, Inc. of Alexandria, VA on August 24, 1993, for "TECHNICAL AND ADMINISTRATIVE SUPPORT FOR THE DIVISION OF HIGH ENERGY PHYSICS."

a. Please explain why these funds were awarded on a non-competitive basis.

A67. This contractor is a small disadvantaged business and was selected for contract under the Small Business Administration's 8(a) Program, in accordance with Federal Acquisition Regulation Subpart 19.8.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards - Fiscal Year 1993

Q67. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC02-93ER40758) of $1,250,000 was made by the Director of Energy Research to the Walcoff & Associates, Inc. of Alexandria, VA on August 24, 1993, for "TECHNICAL AND ADMINISTRATIVE SUPPORT FOR THE DIVISION OF HIGH ENERGY PHYSICS."

b. Please explain why the awardee was/is uniquely qualified to carry this effort.

A67. Selection procedures within the 8(a) program (Federal Acquisition Regulation Subpart 19.8) do not require the small disadvantaged business to be uniquely qualified to carry out the contract activities. The contractor was selected based upon its capability to perform the activities described in the statement of work.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards - Fiscal Year 1993

Q67. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC02-93ER40758) of $1,250,000 was made by the Director of Energy Research to the Walcoff & Associates, Inc. of Alexandria, VA on August 24, 1993, for "TECHNICAL AND ADMINISTRATIVE SUPPORT FOR THE DIVISION OF HIGH ENERGY PHYSICS."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date

A67. While the original contract award specified an estimated total funding amount of $1,250,000, only $410,00 has actually been obligated to date as needed on a task order basis. The award to Walcoff & Associates identified four areas of activity in the Statement of Work: 1) Provide staff support for the handling of research proposals reviewed by the Division; 2) Provide technical/scientific expertise for domestic and international projects; 3) Assist in planning and arranging meetings of the High Energy Physics Advisory Panel, Nuclear Science Advisory Committee, and various committees, panels and subpanels; 4) Produce and distribute reports and evaluations written by DOE officials relative to HEPAP. The first activity has been successfully supported by the contractor on an ongoing basis and the required work is up-to-date.

A change in program priorities subsequent to the award of the contract eliminated the need for the specialized expertise to be provided under the second activity Thus no funding was provided for this activity.

The contractor has provided logistical support for 28 HEPAP and other panel meetings to date. These include 17 extended information gathering, wrap-up and report writing meetings. For example, this contractor provided logistical support for the several meetings of the "Drell" subpanel. In the fourth activity area, the contractor has completed one report and a second report is in process.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards - Fiscal Year 1993

Q68. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG02-93ER14370) of $45,500 was made by the Director of Energy Research to the National Center for Manufacturing Sciences on September 15, 1993, for "INDUSTRIAL LIAISON PILOT PROGRAM."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date.

A68. i) The National Center for Manufacturing Sciences (NCMS) Ann Arbor, Michigan, was to help selected personnel from various DOE National laboratories spend between a year and two years on sabbatical leaves in small and midsize manufacturing plants with no inhouse research capabilities. The object of this award was to give an opportunity to up to four national laboratory technical and scientific personnel to experience "real life" technical manufacturing issues on "the factory floor." Upon return to their home institutions such experience would have helped them formulate research projects on manufacturing technologies and processes within the scope of the mission and capabilities of their parent institutions that would be benefit to such types of manufacturers.

ii) In the end, the Department determined that the awardee, NCMS, would use the remaining funds, almost all of the original $45,500, to participate, by way of a subcontract, in supporting an Integrated Manufacturing Predoctoral Fellowship program administered for DOE by the National Research Council (NRC).

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q69. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG01-94ER76031) of $3,826,305 was made by the Director of Energy Research to the Earth Conservation Corps of Washington, DC on August 8, 1994, for "SALMON CORPSCRESTORE TRADITIONAL GRAVEL SPAWNING BEDS OF COLUMBIA RIVER BASIN SALMON."

a. Please explain why these funds were awarded on a non-competitive basis.

A69. No Office of Energy Research funds were used for this award. Funding for the Department was provided by the Environmental Restoration Program as a part of the Department of Energy's participation in the National Service Program. It is our understanding that there was competition for the funding of National Service Corporation related awards.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q69. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG01-94ER76031) of $3,826,305 was made by the Director of Energy Research to the Earth Conservation Corps of Washington, DC on August 8, 1994, for "SALMON CORPSCRESTORE TRADITIONAL GRAVEL SPAWNING BEDS OF COLUMBIA RIVER BASIN SALMON."

b. Please explain why the awardee was/is uniquely qualified to carry this effort.

A69. The awardee, as part of the selection and award process was determined to be qualified to support the Department's efforts in Environmental Restoration in the Pacific Northwest region of the country.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q69. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG01-94ER76031) of $3,826,305 was made by the Director of Energy Research to the Earth Conservation Corps of Washington, DC on August 8, 1994, for "SALMON CORPSCRESTORE TRADITIONAL GRAVEL SPAWNING BEDS OF COLUMBIA RIVER BASIN SALMON."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date.

A69. The restoration of traditional gravel spawning beds of the Columbia River Basin was the purpose of the National Service Corporation. We believe that most of the objective has been accomplished.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q69. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG01-94ER76031) of $3,826,305 was made by the Director of Energy Research to the Earth Conservation Corps of Washington, DC on August 8, 1994, for "SALMON CORPSCRESTORE TRADITIONAL GRAVEL SPAWNING BEDS OF COLUMBIA RIVER BASIN SALMON."

d. Please explain why restoring "traditional gravel spawning beds of Columbia River Basin Salmon" is a mission of the Office of Energy Research.

A69. This is not a part of the mission of the Office of Energy Research and no funding was provided by this office. As a part of each agency's commitment to the National Service Program, an office was given responsibility for their participation. Within DOE, administration of this program was assigned to the then newly created Office of Science Education and Technical Information that did not report to the Director, Office of Energy Research. Since this was a newly established office, the Office of Energy Research was asked to provide administrative support, which, in this case, merely involved the use of an Office of Energy Research award number only. Energy Research had no involvement other than providing an award number in order that a Procurement Request form could be processed by the Office of Science Education and Technical Information.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q69. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG01-94ER76031) of $3,826,305 was made by the Director of Energy Research to the Earth Conservation Corps of Washington, DC on August 8, 1994, for "SALMON CORPSCRESTORE TRADITIONAL GRAVEL SPAWNING BEDS OF COLUMBIA RIVER BASIN SALMON."

e. Please identify all individuals that have received funding under this award to date, including the (i) name and professional expertise and (ii) the amount of funding.

A69. The only information we have available regarding this Office of Science Education and Technical Information project is that a total of $3,826,305 dollars was provided in the award. The National Service Corporation provided half that funding and the DOE, under the Assistant Secretary for Environmental Management, provided the rest consistent with the National Service Corporation charter. We have asked the Assistant Secretary for Environmental Management to supply you with the information you requested.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q70. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-94ER25182) of $3,115,915 was made by the Director of Energy Research to Information Management Consultants of McLean, VA on February 16, 1994, for "TECH AND ADMIN SUPPORT SERVICES TO THE OFFICE OF ENERGY RESEARCH, ER-30."

a. Please explain why these funds were awarded on a non-competitive basis.

A70. This contractor is a small disadvantaged business and was selected for contract under the Small Business Administration's 8(a) Program in accordance with Federal Acquisition Regulation Subpart 19.8.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q70. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-94ER25182) of $3,115,915 was made by the Director of Energy Research to Information Management Consultants of McLean, VA on February 16, 1994, for "TECH AND ADMIN SUPPORT SERVICES TO THE OFFICE OF ENERGY RESEARCH, ER-30."

b. Please explain why the awardee was/is uniquely qualified to carry this effort.

A70. Selection procedures within the 8(a) program (Federal Acquisition Regulation Subpart 19.8) do not require the small disadvantaged business to be uniquely qualified to carry out the contract activities. The contractor was selected based upon its capability to perform the activities described in the statement of work.

QUESTION FROM REPRESENTATIVE ROHRABACKER

Non-Competitive Awards-Fiscal Year 1994

Q70 According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-94ER25182) of $3,115,915 was made by the Director of Energy Research to Information Management Consultants of McLean, VA on February 16, 1994, for "TECH AND ADMIN SUPPORT SERVICES TO THE OFFICE OF ENERGY RESEARCH, ER-30."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date.

A70. i) At the award date, the following major tasks were to be accomplished by the Support Services Contract with Information Management Consultants, Inc. (IMC).

a) Support the Information Technology Steering Working Group meetings (Federal Government wide Sub group **Government Information Technology Services [GITS]**, which reports to the Committee on Information Communication, [CIC], b) document preparation, c) technology scanning and business plan development.

ii) The following has been accomplished: Information Management Consultants, Inc., in support of Information Technology Steering Working Group meetings concerned with Information Technology, has participated widely, and specifically has furnished personnel to act as the Executive Director of the ESnet Steering Committee.

IMC personnel orchestrated an ongoing review of the Energy Sciences Network (ESnet) committee chairmanship, committee structure, and membership and actively participated in new technology steering, architecture and deployment meetings.

IMC furnished personnel to act as the Executive Director of the ESnet Site Coordinators Committee and actively participated in discussions on technical issues relevant to the architecture and functioning of ESnet and implementation strategies for new technology. IMC furnished personnel to serve on the ER Information Technology wide committees dealing with issues connected with the World Wide Web, DOE Networking Infrastructure and video conferencing.

IMC, in support of document preparation, technology scanning, and business plan development have: reviewed for suitability a pilot project for utilizing Lotus Notes as a paradigm for a "paperless office"; deployed a multi-user accessible budget database to augment the business plan; and introduced new technology, such as the Web, Linnux, UNIX, CD-ROM, and multipurpose new technology color printers. IMC has actively participated in the development of the ESnet Strategic Plan; scanned new technology for applicability to the DOE MICS Mission (specifically - multiplatform and multioperating system workstations, projection capable laptops for on the road presentations, and telecommuting, high speed local networks for packet based desktop video conferencing.)

IMC in support of the initiative and the National Information Infrastructure (NII) have furnished personnel that acted as backup to the primary DOE person for two years in the multiagency meetings wherein the HPCC status report was created (the so called "Blue Book"). IMC furnished the technical help in gathering the relevant information needed for the Blue Book from the internet and the web.

IMC personnel created the status report on DOE's HPCC contributions and research (the so called "White Book") not only as a hard copy, but also as a report on the web

IMC resources to create an office desk-top environment that is capable of handling documents and images from any computer environment (operating system and application) commonly encountered from among the other agencies participating in the initiative.

IMC provided technical and management support for the OSC telecommuting pilot project. Information Management Consultants, Inc., in support of the OSC (now, MICS) telecommuting pilot project have evaluated three models of laptops for their applicability in a nomadic work environment, whiteboard technology, multicast video software, remote access software (Reachout, etc.) and remote web accessibility.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q71. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG02-94ER75981) of $54,574 was made by the Director of Energy Research to the Association for Women in Science of Washington, DC, on May 24, 1994, for "A PROPOSAL FOR A LEADERSHIP CONFERENCE, WOMEN [SIC] SCIENCE AND ENGINEERING LEADERSHIP: TAKING THE INITIATIVE."

a. Please explain why these funds were awarded on a non-competitive basis.

A71. This grant is incorrectly listed as a non-competitive award. It was competitively selected under the Office of Energy Research Financial Assistance Program codified at 10 CFR Part 605.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q71. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG02-94ER75981) of $54,574 was made by the Director of Energy Research to the Association for Women in Science of Washington, DC, on May 24, 1994, for "A PROPOSAL FOR A LEADERSHIP CONFERENCE, WOMEN [SIC] SCIENCE AND ENGINEERING LEADERSHIP: TAKING THE INITIATIVE."

b. Please explain why the awardee was/is uniquely qualified to carry this effort.

A71. Not applicable since this was a competitively selected award.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q71. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG02-94ER75981) of $54,574 was made by the Director of Energy Research to the Association for Women in Science of Washington, DC, on May 24, 1994, for "A PROPOSAL FOR A LEADERSHIP CONFERENCE, WOMEN [SIC] SCIENCE AND ENGINEERING LEADERSHIP: TAKING THE INITIATIVE."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date.

A71. i) The Association for Women in Science hosted the aforementioned leadership conference in Washington DC, May 12-14, 1994. The purpose of the conference was to prepare women scientists and engineers to enter new leadership positions in science and in scientific organizations. The central idea of the conference was that leadership is a process that effects change in organizations. With a clear understanding of what leadership is and what it can accomplish, coupled with insight into one's own competencies, women scientists and engineers can become leaders with impact.

ii) The specific objectives of the conference were for participants to know what leadership is; recognize the purpose of and need for leadership; distinguish when one is "doing" leadership or management at work; understand the elements of the leadership process; gain insight into one's own leadership strengths and style and needs for further development; learn how to apply the leadership process to workplace problems; acquire a framework for teaching others about the leadership process; and develop a personal "contract" for leadership development. Regional groups were formed, including participants from NASA, DOE and AWIS, to develop a plan for taking the information learned at the conference back to women in their local areas.

Follow-up meetings were held at the local level with women who did not have the opportunity to attend the conference. Conference proceedings were published and disseminated.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1994

Q71. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG02-94ER75981) of $54,574 was made by the Director of Energy Research to the Association for Women in Science of Washington, DC, on May 24, 1994, for "A PROPOSAL FOR A LEADERSHIP CONFERENCE, WOMEN [SIC] SCIENCE AND ENGINEERING LEADERSHIP: TAKING THE INITIATIVE."

d. Please identify all individuals that received funding under this award to date, including the i) name and professional expertise and ii) the amount of funding.

A71. This leadership conference was jointly funded by the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA) and the Association for Women in Science (AWIS) for a total budget of $106,360. AWIS absorbed the indirect costs of $4586. NASA funding of $47,200 provided $22,000 for conference costs, and $25,200 for travel, meals, and lodging for approximately 50 participants. DOE provided $54,574 in funds to cover $45,000 in travel and lodging for the remaining 100 participants, and costs for publications and some materials and supplies for the conference. 152 conference participants included 43 from DOE, 39 from NASA, 56 from AWIS and 14 from other organizations. Travel expenses for DOE employees and contractors were not covered by this grant, but by DOE. Because this was a jointly funded conference by NASA and DOE costs per individual participants are not available.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q72. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-95ER30227) of $507,000 was made by the Director of Energy Research to Kira Inc. of Washington, DC, on December 9, 1994, for "SUPPORT SERVICE CONTRAST [sic] FOR THE OFFICE OF SCIENCE AND TECHNOLOGY AFFAIRS STAFF."

a. Please explain why these funds were awarded on a non-competitive basis.

A72. This contractor is a small disadvantaged business and was selected for contract under the Small Business Administration's 8(a) Program, in accordance with Federal Acquisition Regulation Subpart 19.8.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q72. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-95ER30227) of $507,000 was made by the Director of Energy Research to Kira Inc. of Washington, DC, on December 9, 1994, for "SUPPORT SERVICE CONTRAST [sic] FOR THE OFFICE OF SCIENCE AND TECHNOLOGY AFFAIRS STAFF."

b. Please explain why the awardee was/is uniquely qualified to carry this effort.

A72. Selection procedures within the 8(a) program (Federal Acquisition Regulation Subpart 19.8) do not require the small disadvantaged business to be uniquely qualified to carry out the contract activities. The contractor was selected based upon its capability to perform the activities described in the statement of work.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q72. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-95ER30227) of $507,000 was made by the Director of Energy Research to Kira Inc. of Washington, DC, on December 9, 1994, for "SUPPORT SERVICE CONTRAST [sic] FOR THE OFFICE OF SCIENCE AND TECHNOLOGY AFFAIRS STAFF."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date.

A72. i) The subject contract provides for support to the Office of Planning and Analysis in:

a) discharging its responsibilities to the Director of Energy Research under pertinent energy legislation or other agency directives; b) developing new initiatives that support increased emphasis on "reinventing" government; c) supporting the development of and the implementation of a new strategic plan consistent with the downsizing of the agency as a whole, and of ER in particular.

ii) In support of these objectives, KIRA has assisted in the design, development, and review of the contract reform initiative; in the development and review and tracking of program deliverables; in the initiation of new initiatives between ER and EM in basic science, including the Airlie Workshop in 1995 and the current workshops being held at Savannah River and Hanford to involve stakeholders in the environmental management science initiative process; in the assembling and documentation of ER success stories in the preparation of numerous reports and presentations and documents related to R&D Management, the Strategic Laboratory Mission Plan, and the Laboratory Operating Board.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q73. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-95ER30239) of $63,865 was made by the Director of Energy Research to the Keystone Center of Keystone, CO, on March 9, 1994, for "BASIC SCIENCE AND IT'S [sic] RELATIONSHIP TO PROBLEMS IN THE ENVIRONMENT; PREPARING FOR THE 21ST CENTURY."

a. Please explain why these funds were awarded on a non-competitive basis.

NOTE: **We are unable to reconcile all of the information contained in question 73. The following information pertains to competitive award (AC01-95ER30239) with Keystone Center of Keystone, CO. However, the funding for that effort was $68,146, rather than $63,865, and the award date was March 9, 1995, rather than March 9, 1994.**

A73. Keystone was given the award non-competitively under 10 C.F.R. 600.7(b) (2) (i) (D), on the basis that it had the exclusive capability to perform the activity successfully, based upon technical expertise and unique qualifications.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q73. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-95ER30239) of $63,865 was made by the Director of Energy Research to the Keystone Center of Keystone, CO, on March 9, 1994, for "BASIC SCIENCE AND IT'S [sic] RELATIONSHIP TO PROBLEMS IN THE ENVIRONMENT; PREPARING FOR THE 21ST CENTURY."

b. Please explain why the awardee was/is uniquely qualified to carry this effort.

NOTE: **We are unable to reconcile all of the information contained in question 73. The following information pertains to competitive award (AC01-95ER30239) with Keystone Center of Keystone, CO. However, the funding for that effort was $68,146, rather than $63,865, and the award date was March 9, 1995, rather than March 9, 1994.**

A73. The Keystone Center has a long history of conducting independent evaluations of public policy issues. The organization has demonstrated the unparalleled ability to bring together world-renowned experts in the subject areas on a short time frame and to elicit from them opinions and possibilities of direct and immediate benefit. Keystone was deemed uniquely qualified to conduct this conference because of its experience in the area of science and technology policy.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q73. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-95ER30227) of $63,865 was made by the Director of Energy Research to the Keystone Center of Keystone, CO, on March 9, 1994, for "BASIC SCIENCE AND IT'S [sic] RELATIONSHIP TO PROBLEMS IN THE ENVIRONMENT; PREPARING FOR THE 21ST CENTURY."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date

NOTE: **We are unable to reconcile all of the information contained in question 73. The following information pertains to competitive award (AC01-95ER30239) with Keystone Center of Keystone, CO. However, the funding for that effort was $68,146, rather than $63,865, and the award date was March 9, 1995, rather than March 9, 1994.**

A73. On April 5-6, 1995, a workshop was held at the Airlie House in Airlie Virginia. It was attended by 23 participants representing government (DOE, EPA, NIH, NSF, the White House), industry (Rust Engineering, IBM, Lockheed Martin, Monsanto, Ford), universities (Columbia, UC/Berkeley, Portland State, URA, UC/San Francisco), non-profit community (National Audubon, Boyce Thomson Institute), and the national laboratories (Sandia, Pacific Northwest, Argonne). The two-day workshop was convened to address the problem of bringing more basic science to the environmental program of the nation, in particular to the work sponsored by DOE. Specific questions addressed during the workshop were: a) What environmental problems can be effectively addressed through basic science? b) Are there multi-disciplinary artnerships within universities that should be formed to address these environmental program? c) What is necessary to get the "best" minds in the university and national laboratory communities actively engaged in addressing fundamental environmental problems? d) If such a beginning can be made, how should its significance be communicated to other agencies?

A full report was issued by the Keystone Center in September 1995 and circulated to all participants and to DOE. The importance of this workshop to the implementation of the new Environmental Management Science Program cannot be underestimated. The Environmental Management Science Program responds to a congressional mandate stated in the conference report on the Fiscal Year 1996 Energy Water Appropriations Act which directs the Department of Energy to focus on long term basic science research as the key to developing innovative and cost-effective environmental management technologies. The decision to create such a program follows through on recommendations from stakeholder groups, including environmental experts from the National Academy of Sciences and the Secretary of Energy Advisory Board (Galvin Commission). While the Environmental Management Science Program was not the only pressure being brought to bear on DOE to initiate a more focussed basic science program in support of EM programs, it was part of the growing realization (Galvin report, EM/ER discussions) that DOE needed to give serious consideration to finding a way to use basic science as a new tool to address environmental problems.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q73. According to information received from the DOE Chief Financial Officer, a non-competitive award (AC01-95ER30227) of $63,865 was made by the Director of Energy Research to the Keystone Center of Keystone, CO, on March 9, 1994, for "BASIC SCIENCE AND IT'S [sic] RELATIONSHIP TO PROBLEMS IN THE ENVIRONMENT; PREPARING FOR THE 21ST CENTURY."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date.

NOTE: **We are unable to reconcile all of the information contained in question 73. The following information pertains to competitive award (AC01-95ER30239) with Keystone Center of Keystone, CO. However, the funding for that effort was $68,146, rather than $63,865, and the award date was March 9, 1995, rather than March 9, 1994.**

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A full report was issued by the Keystone Center in September 1995 and circulated to all participants and to DOE. The importance of this workshop to the implementation of the new Environmental Management Science Program cannot be underestimated. The Environmental Management Science Program responds to a congressional mandate stated in the conference report on the Fiscal Year 1996 Energy Water Appropriations Act which directs the Department of Energy to focus on long term basic science research as the key to developing innovative and cost-effective environmental management technologies. The decision to create such a program follows through on recommendations from stakeholder groups, including environmental experts from the National Academy of Sciences and the Secretary of Energy Advisory Board (Galvin Commission). While the Environmental Management Science Program was not the only pressure being brought to bear on DOE to initiate a more focussed basic science program in support of EM programs, it was part of the growing realization (Galvin report, EM/ER discussions) that DOE needed to give serious consideration to finding a way to use basic science as a new tool to address environmental problems.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q74. According to information received from the DOE Chief Financial Officer, a non-competitive award (FC-95ER62062) of $63,865 was made by the Director of Energy Research to the National Center for Genome Resources of Sante Fe, NM, on September 26, 1995, for "ESTABLISHMENT AND OPERATION OF A GENOME DATA BASE."

a. Please explain why these funds were awarded on a non-competitive basis.

NOTE: We are unable to reconcile all of the information contained in question 74. The following information pertains to competitive award (FC-95ER62062) with the National Center for Genome Resources of Sante Fe, NM. However, the title of that effort is "GENOME SEQUENCE DATA BASE" rather than "ESTABLISHMENT AND OPERATION OF A GENOME DATA BASE," and the funding for that effort was $1,100,061, rather than $63,865.

A74. This grant was incorrectly identified as a non-competitive award. It was competitively selected under the Office of Energy Research Financial Assistance Program Rule codified at 10 CFR Part 605.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q75. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG05-95ER30247) of $50,000 was made by the Director of Energy Research to SIGMA XI of Durham, NC, on March 1, 1995, for "SIGMA XI 1995 FORUM-VANNEVAR BUSH II SCIENCE FOR THE 21ST CENTURY TO BE HELD MARCH 2-3, 1995.

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date.

A75. i) This award enabled Sigma XI, The Research Society, to conduct the 1995 Sigma Xi forum March 2-3, 1995. The mission of Sigma Xi is to encourage and enhance worldwide appreciation and support of original investigation in science and technology. The two day conference featured 12 primary speakers and 10 panels.

ii) Funding provided by the Department of Energy under this grant enabled the Sigma Xi to publish the proceedings of the forum and make them available to all forum participants, officers of Sigma Xi's more than 500 chapters, members of Congress and the media.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q76. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG03-95ER45536) of $100,000 was made by the Director of Energy Research to the University of Tennessee in Knoxville, on June 5, 1995, for "PAN AMERICAN ADVANCED STUDY INSTITUTE."

a. Please explain why these funds were awarded on a non-competitive basis.

A76. This grant is incorrectly listed as a non-competitive award. It was competitively selected under the Office of Energy Research Financial Assistance Program codified at 10 CFR Part 605.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q76. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG03-95ER45536) of $100,000 was made by the Director of Energy Research to the University of Tennessee in Knoxville, on June 5, 1995, for "PAN AMERICAN ADVANCED STUDY INSTITUTE."

b. Please explain why the awardee was/is uniquely qualified to carry this effort.

A76. Not applicable, since it was a competitively selected award.

QUESTIONS FROM REPRESENTATIVE ROHRABACHER

Non-Competitive Awards-Fiscal Year 1995

Q76. According to information received from the DOE Chief Financial Officer, a non-competitive award (FG03-95ER45536) of $100,000 was made by the Director of Energy Research to the University of Tennessee in Knoxville, on June 5, 1995, for "PAN AMERICAN ADVANCED STUDY INSTITUTE."

c. Please explain in detail (i) what was to be accomplished by this award at the date of the award, and (ii) what has been accomplished to date.

A76. i) This application from the University of Tennessee was funded based on a competitive merit review process. The purpose was to provide short, intense advanced courses in the areas of high-temperature superconductors, composites, structural ceramics, diamond and related materials, nanostructured materials, cement-based materials, and micro-electronic materials.

ii) These courses were at the advanced graduate student and post-doctoral level. The courses were structured to impart to the participants the current, most advanced status of research in the areas selected. The courses were held during August 13-25, 1995 in Merida, Yucatan, Mexico. There were 89 students and 11 professors from ten countries. The courses were co-sponsored by the National Science Foundation, the Consejo Nacional de Ciencia Y Tecnologia (Mexico), Consejo Nacional de Desenvolvimiento Cientifico y Tecnologico (Brazil), and the Mexican Academy of Materials.

QUESTION FROM REPRESENTATIVE ROHRABACHER

Use of Prior Year Balances and Other Adjustments

Q77. The FY 1997 budget request for the Energy Supply R&D appropriations account includes a negative total of -$48,177,000 on the line "Use of Prior Year Balances and Other Adjustments." In response to a questions by House Energy and Water Development Appropriations Chairman Myers, DOE's Chief Financial Officer Vivona replied that this request would result in a general reduction of $21.203 million to Energy Research. (See page 1164 of *ENERGY AND WATER DEVELOPMENT APPROPRIATIONS FOR 1997: Hearings before a Subcommittee of the Committee on Appropriations, House of Representatives, One Hundred Fourth Congress, Second Session*, Subcommittee on Energy and Water Development, Part 5.) What will be the impact of this general reduction on Energy Research programs?

A77. Biological and Environmental Research

The reduction of $6,217,000 for the Biological and Environmental Research program will slow and curtail research aimed at improving healthcare and the environment in which we live. The human genome program will be delayed, reducing the production DNA sequencing by four to five million fewer bases This delays the availability of the raw material necessary to understand gene function and develop new medical diagnostic and therapeutic tools. The data and tools necessary for improving the prediction of global change will be slowed, limiting science-based environmental and energy policy decisions. Radiopharmaceutical research targeted on heart disease, prostate cancer, and mental disorders will be curtailed with the consequent societal impacts. The direct employment impact will include some 20 new jobs not realized and about 20 scientists, graduate students, and technicians will lose their financial support. Five national laboratories and four to six universities will be affected.

Basic Energy Sciences

A reduction of $6,432,000 in FY 1997 would result in a loss of core research programs at the laboratories and at universities. Very approximately, for each reduction of $200,000 at a national laboratory, 1 Ph.D. and 1 support staff (technician, secretary,...) job are lost. For each reduction of $200,000 at a university, 2 graduate students and 1 postdoc are lost. Assuming that about 2/3 of the funds would be taken from the laboratories and 1/3 of the funds would be taken from universities, this would result in the loss of 20 Ph.D. scientists and engineers and 20 technical and support staff at the laboratories, 20 graduate students and 10 postdocs in universities. This would impact all fields supported by Basic Energy Sciences -- materials sciences, chemical sciences, geosciences, biosciences, and engineering. This reduction would require immediate program terminations with no phase out period for staff, students, or postdocs.

Computational and Technology Research

A reduction of $3,913,000 in FY 1997 would reduce support for high performance computing facilities located at the national laboratories that provide support to research activities throughout the Department. The Adventures in Supercomputing Program would also be reduced. Support of Technology Research collaborations and Advanced Energy Projects would also be reduced.

Multiprogram Energy Laboratories - Facilities Support

The impact of the $60,000 general reduction would reduce ES&H compliance activities.

Energy Research Analyses

The impact of the $177,000 general reduction would reduce support for peer review activity.

University and Science Education

The $1,515,000 reduction in the University and Science Education request will have the following result:

Laboratory Cooperative Program (KT01)

The DOE Distinguished Posdoctoral program will be reduced by $300,000 and the program may have to be phased out.

Laboratory Cooperative Program efforts for undergraduate, graduate students and faculty will be reduced by $300,000. The reduction will result in fewer laboratories participating in the program and a commensurate reduction in the number of students achieving hands on experience.

University Programs (KT02)

The DOE laboratory partnership and consortia efforts with Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs) and other minority institutions will be reduced by $915,000. The reduction will eliminate one DOE laboratory and approximately two of the HBCU/HSI institutions from collaborative research and faculty/student development participation with DOE National Laboratories.

Energy Research - Energy Supply, Research and Development Program Direction

This reduction will further reduce support for the Federal staff managing these R&D programs by $564,000. As a part of the Office of Energy Research streamlining initiatives, we had already reduced our FY 1997 request by more than a million dollars from FY 1996 comparable levels. Our ability to manage and execute these important programs in a cost efficient manner will be impeded by this further reduction in support.

Fusion Energy Sciences

Of the $2,325,000 reduction allocated to the Fusion Energy Sciences Program, $1,425,000 would be taken from the proposed $54.0 million budget for the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory, and the remainder ($0.9 million) would be taken from U.S. support to the ITER Engineering Design Activities. The impact of such a reduction on TFTR would be a 20% loss in operating time (6 weeks lost out of 30 weeks planned for FY 1997). This would seriously diminish the scientific opportunity to obtain unique physics information from the use of enhanced confinement techniques prior to final shut down of the TFTR facility.

The $900,000 lost from the FY 1997 ITER budget request ($55.0 million) would reduce the scope of several R&D tasks that have been assigned to the United States by the ITER Joint Central Team. These general reductions would affect ongoing work at General Atomics and Oak Ridge National Laboratory. The scope reductions will be chosen so as not to jeopardize the overall success of the ITER Engineering Design Activities; however, the reduced scope would have to be accomplished at a later date.

QUESTION FROM REPRESENTATIVE ROHRABACHER

SBIR and STTR Programs

Q78. Please provide total OER funding, by program budget account (i.e., BER, BES, Fusion, High Energy Physics, Nuclear Physics, etc.), for each of the SBIR and STTR programs for each of FY 1993, FY 1994, FY 1995, FY 1996, and FY 1997.

A78. I will be happy to provide you that information in a table for the record.

SBIR Funding
(B/A in thousands)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	
Basic Energy Sciences	$8,838	$8,784	$12,219	$13,647	$14,434	
Computational and Technology Research	0	0	0	0	3,789	a/
Advanced Neutron Source	0	243	393	0	0	
Fusion Energy Sciences	4,562	4,559	6,848	4,651	5,600	
High Energy Physics	7,265	7,067	9,494	9,530	12,185	
Nuclear Physics	2,478	3,221	4,508	4,110	5,443	
Superconducting Super Collider	1,587	0	0	0	0	
Biological and Environmental Research	4,546	4,700	6,390	6,150	7,823	
University and Science Education	832	825	1,078	368	498	
Technology Transfer	146	559	1,132	276	a/	
Energy Research Analyses	59	55	66	62	50	
Multiprogram Energy Laboratories- Facilities Support	0	26	142	133	286	
Total Office of Energy Research	$30,313	$30,039	$42,270	$38,927	$50,008	

a/ New decision unit in FY 1997 - combines Technology Transfer, Advanced Energy Projects, Applied Mathematical Sciences, and the MFE Computer Center from Fusion Energy Sciences. FY 1995 and FY 1996 are not comparable for new structure in FY 1997.

STTR Funding
(B/A in thousands)

	FY 1994	FY 1995	FY 1996
Basic Energy Sciences	$293	$611	$1,022
Advanced Neutron Source	8	20	0
Fusion Energy Sciences	152	342	341
High Energy Physics	236	475	715
Nuclear Physics	107	225	308
Biological and Environmental Research	158	319	461
University and Science Education	28	54	28
Technology Transfer	19	57	21
Energy Research Analyses	2	3	5
Multiprogram Energy Laboratories-Facilities Support	1	7	10
Total Office of Energy Research	$1,004	$2,113	$2,911

QUESTION FROM REPRESENTATIVE ROHRABACHER

SBIR and STTR Programs

Q79. Please identify the recipients of all DOE SBIR and STTR funding awards for each of FY 1993, FY 1994, FY 1995, FY 1996, and FY 1997, including (a) the amount of award, and (b) a brief description of the justification for each award.

A79. The attached documents respond to your questions and are being provided for the record.

(1) SBIR awards: Phase I and Phase II awards for FY 1993, FY 1994, and FY 1995. For FY 1996, only Phase I awards have been selected at the present time, and the abstract book has not yet been prepared (a listing of awards is provided). Awards for FY 1997 will be made in the June-July 1997 timeframe.

(2) STTR awards: Phase I awards for FY 1994 (the first year of the STTR program) and Phase I and Phase II awards for FY 1995. For FY 1996, only Phase I awards have been selected at the present time, and the abstract book has not yet been prepared (a listing of awards is provided). If the STTR pilot program is reauthorized, awards for FY 1997 will be made in the June-July FY 1997 timeframe.

The amount of each award is listed in the attached abstract books. In FY 1996, each SBIR Phase I award in FY 1996 was for approximately $75,000, and each STTR Phase I award was for approximately $100,000.

Regarding the justifications for these awards, a copy of the selection statement is provided for each set of awards. The selection statement for FY 1996 SBIR Phase I awards has not yet been prepared.

DEPARTMENT OF ENERGY

SBIR

1993

PHASE I AND

PHASE II

AWARDS

SELECTION STATEMENT FOR PHASE I AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM FOR FISCAL YEAR 1993 (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0559)

U. S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585
JULY 20, 1993

SELECTION OF GRANT APPLICATIONS FOR NEGOTIATION OF SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM PROJECTS FOR FISCAL YEAR 1993 UNDER PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0559

As a former chairman of the SBIR Application Score Verification Panel appointed to evaluate Phase I applications for the SBIR program, I am familiar with the Panel's evaluation procedures and its methodology. I have received reports from the Technical Topic Managers (TTMs) who were responsible for the review of the 37 technical topic areas listed in the solicitation. I believe that the Panel and the TTMs have proceeded in accordance with applicable laws and regulations, that the evaluation has been thorough and equitable, and that the information presented forms a sound basis for selection. Consequently, I have selected 171 applications received under this solicitation for negotiation for award of Phase I Fiscal Year (FY) 1993 SBIR grants. This statement describes the procurement and sets forth the basis for my selection decision.

Procurement Description

The Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564), requires that each Federal agency with an extramural research or research and development budget exceeding $100 million establish an SBIR program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies over the 18 years of the program are as follows:

Fiscal Year	SBIR Set Aside (%)
1983	0.2
1984	0.6
1985	1.0
1986-1992	1.25
1993-1994	1.5
1995-1996	2.0
1997-2000	2.5

Public Laws 97-219 and 102-564 also prescribe that the SBIR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the SBIR program. This phase will have a period of performance which is typically six months in duration. Awards will be up to $75,000 for FY 1993 Phase I projects. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $600,000 for FY 1994 Phase II projects. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-SBIR funded Federal contracts for products or services intended for use by the U.S. Government.

In response to the first ten program solicitations for FY 1983-1992, DOE received a total of 11,944 Phase I proposals. Of these proposals, 1,353 resulted in Phase I contracts or grants, and of these 636 were subsequently selected for Phase II awards. The results of the 1993 Phase I grant applications discussed here will be added to the above figures which demonstrate the high level of volume and interest in the SBIR program.

Applications Received

Outreach efforts for the DOE SBIR program were considerable. DOE mailed out approximately 30,000 1993 solicitations to past recipients on an extensive mailing list and to other individuals requesting copies. In addition, the SBIR solicitation was advertised in the Commerce Business Daily on October 30, 1992. It also received coverage in trade journals and newsletters and in various Small Business Administration information releases and conferences.

A total of 1,999 applications was received in response to the solicitation. The solicitation listed 37 technical topic areas to which applicants could respond. The list of technical topic areas and the number of applications received in each area is as follows:

1.	Advanced Environmental Control Technology for Fossil Energy	149
2.	Increased Coal Utilization, Advanced Combustion, and CO_2 Reduction Techniques	72
3.	Coal Beneficiation and Transport	57
4.	Advanced Technology for the Recovery, Storage, and Utilization of Natural Gas	113
5.	Coal-Based Power Systems Technology	68
6.	Enhanced Oil Recovery	67
7.	Advanced Fossil Resource Utilization	74
8.	Climate Control Technologies for Transportation Systems	78
9.	Chemical Products from Biomass	23
10.	Biomass Electric Power Technology	6
11.	Advanced Window and Glazing Technologies	66
12.	Educational Technologies	151
13.	Chronic Beryllium Disease	3
14.	Health Effects	11
15.	Human Genome	35
16.	Biotechnology: Structural Biology and Molecular Nuclear Medicine	25
17.	Instrumentation for Ocean Measurements	33
18.	Design and Applications of Novel Materials	175
19.	Biomolecular Separations	8
20.	Advanced Geophysical Imaging in Geosciences Research	27
21.	Chemical Sciences Research	130
22.	Materials Sciences Instrumentation	38
23.	High Performance Computing Research	66
24.	Technology for the Superconducting Super Collider	52

25.	Technology and Instrumentation for High Energy Accelerators	41
26.	High Energy Physics Data Processing and Detector Instrumentation	38
27.	Nuclear Physics Instrumentation and Techniques	35
28.	Accelerator Technology for Nuclear Physics	12
29.	Special Instrumentation for Nuclear Cross Section Measurements	10
30.	Plasma Confinement Systems Technology	58
31.	Fusion Energy Systems	17
32.	Plasma Diagnostics	26
33.	Technology and Instrumentation for Heavy Ion Fusion Accelerators	8
34.	Robotics and Remote Operations in Civilian Nuclear Reactor Facilities	58
35.	Technology for Space Nuclear Propulsion and Power	77
36.	Technology to Support and Improve Nuclear Fuel Cycle Processes	31
37.	Enrichment of Uranium for Civilian Nuclear Power Reactors	52

Nine applications received could not be assigned to a specific topic or subtopic.

Of the 1,999 applications received, 113 were eliminated for administrative reasons; DOE staff determined that these applications failed to meet one or more material requirements of the solicitation. Two applications were withdrawn by the proposing firms.

The remaining 1,884 were judged on a competitive basis in a two-step process. The first step of that process was a screening by the TTMs and DOE staff knowledgeable in the topic area to determine the relevance of each application to a chosen topic by the extent to which it responded to a specific topic area. Then it was determined whether each application was for research or research and development, whether it provided sufficient information for a full evaluation, whether it was duplicative of other ongoing or previous efforts, and finally, whether it was of sufficiently high quality for award. Four hundred seventy-two applications were eliminated after the first step technical review. The 1,412 applications found to be relevant were evaluated in the second step according to criteria listed in the solicitation and set out below.

Selection Criteria and Rationale

Phase I awards were made on scientific and technical merit based upon the criteria listed below. Approximately equal consideration was given to each of the following criteria:

(1) The scientific/technical quality of the research in the Phase I grant application.

(2) The degree of innovation demonstrated by the grant application.

(3) The qualifications of the Principal Investigator, other key staff, and consultants, if any, and the level of adequacy of available or obtainable instrumentation and facilities.

(4) The anticipated benefits, technical and/or economic, of the proposed research (Phase I and Phase II), if successful, with special emphasis on the likelihood that the project will attract further funding for product or process development after the SBIR support expires.

(5) The soundness and level of adequacy of the Phase I proposed work plan to show progress toward proving the feasibility of the concept.

For each of the 37 technical topic areas listed in the solicitation, there was a TTM who, along with reviewers both internal to DOE and external - selected from among DOE Laboratory personnel, university researchers, and private industry personnel - evaluated and scored applications against the assigned criteria. An Application Score Verification Panel (ASVP) consisting of technical staff from both within and without DOE was established to ensure relative uniformity of scoring across the 37 topic areas and to ensure that scores were based on meaningful technical reviews. The ASVP was also chartered to ensure that there was consistency of scoring within topics.

I have examined the evaluation documentation presented by the TTMs. I have also carefully reviewed the recommendations of the ASVP and have agreed that the evaluations of the TTMs and the recommendations of the ASVP provided valid bases upon which to make a selection. Therefore, based on those recommendations, and in consideration of applications whose funding would contribute to a programmatically-balanced set of SBIR-supported projects, I have selected 171 applications for negotiations. Included in these are all applications which received the highest possible technical rating. The remainder was selected from among applications that were rated one point below the highest possible technical rating, on the basis of (1) program balance and (2) the amount of Phase III funding received for previous DOE SBIR Phase II projects. It is my view that these applications represent outstanding technical quality and are worthy of selection for this program.

Selected Applications

Appendix A is a listing of the applications selected for negotiations leading to award. The SBIR program is an ongoing one, and continued participation in later solicitations is strongly encouraged.

Samuel J. Barish

Samuel J. Barish
SBIR Program Manager

Date: 7/20/93

Attachment:
List of Grant Applications
Recommended for Awards

APPENDIX A
DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1993 AWARDS

TOPIC: ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY FOR FOSSIL ENERGY

ADA Technologies, Inc. 304 Inverness Way South, Suite 110 Englewood, CO 80112	An Innovative Continuous Emissions Monitor for Air Toxic Metals
ADA Technologies, Inc. 304 Inverness Way South, Suite 110 Englewood, CO 80112	Non-Toxic Additives for Improved Fabric Filter Performance
ADA Technologies, Inc. 304 Inverness Way South, Suite 110 Englewood, CO 80112	Real-Time Continuous Analysis of Total and Elemental Mercury
ADA Technologies, Inc. 304 Inverness Way South, Suite 110 Englewood, CO 80112	Removal of Volatile Metals from High Temperature Coal Conversion Gas Streams
Advanced Fuel Research, Inc. P.O. Box 380379 East Hartford, CT 06138-0379	An Instrument for In-Situ Analysis of Carbon in Fly Ash
Ceramic Composites, Inc. 1110 Benfield Boulevard Millersville, MD 21108	Oxide-Based Ceramic Composite Hot Gas Filter Development
Core Technologies, Inc. P.O. Box 1744 1400 First Interstate Plaza Tacoma, WA 98401	Direct Sulfur Reduction in Advanced Coal Conversion Processes
DB Environmental Laboratories, Inc. 414 Richard Road, Suite 1 Rockledge, FL 32955	An Evaluation of Two Pelletized Coal Fly Ashes as Substrates for Subsurface Flow Wetland Wastewater Treatment Systems

Industrial Filter and Pump Manufacturing Company 5900 Ogden Avenue Cicero, IL 60650	A Method for the Reduction of Dust Cake Adhesion in Ceramic Filter Systems
Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706	Innovative Silicon Carbide Fiber Composite Filters
Physical Sciences, Inc. 20 New England Business Center Andover, MA 01810	Measurement of Mercury and Other Trace Metals in Combustion Gases
Poulos Technical Services, Inc. 7 Waterbury Court Allentown, NJ 08501	A Photo-Fragment Fluorescence Spectrometric Method for Measurement and Speciation of Mercury Emissions
PSI Technology Company 20 New England Business Center Andover, MA 01810	Control of Mercury and Other Volatile Trace Metals in Fossil and Fuel-Fired Power Generation
Sorbent Technologies Corporation 1935 East Aurora Road Twinsburg, OH 44087	Catalytic Production of Elemental Sulfur from Sulfur Dioxide-Containing Gas Streams
VirTek 618 Burroughs Road Boxboro, MA 01719	A Method and Apparatus to Monitor Air Toxics
Vortec Corporation 3770 Ridge Pike Collegeville, PA 19426	Glass-Ceramic Construction Tiles from Coal-Fired Boiler Flyash

TOPIC: INCREASED COAL UTILIZATION, ADVANCED COMBUSTION, AND CO_2 REDUCTION TECHNIQUES

BlazeTech Corporation 145 Highland Avenue Winchester, MA 01890	A Low Nitrogen Oxide Burner for Coal Combustion

Coal Tech Corporation P.O. Box 154 Merion Station, PA 19066	Control of Dioxin Emissions from Waste Fuel Combustion by Cofiring with Coal
ERC, Inc. P.O. Box 417 Tullahoma, TN 37388	A T-Layer Magnetohydrodynamic Generator
ERC, Inc. P.O. Box 417 Tullahoma, TN 37388	Remote Sensing Diagnostics for Magnetohydrodynamic Environments
Montec Associates, Inc. P.O. Box 4182 Butte, MT 59702	A Testing Process to Define Electrode Current Wear Mechanisms and Develop Improved Electrodes
Reaction Engineering International 44 West 300 South, Suite 2306S Salt Lake City, UT 84101	An Environmentally Sound Process for Utilizing Waste Tire-Derived Fuel (TDF) and Railroad-Tie-Derived Fuel (RTDF) in Coal-Fired Stoker Boilers
Spinheat Limited 1222 Bronson Road Fairfield, CT 06430	Development of a Rotary Combustor for Refiring Pulverized Coal Boilers

TOPIC: COAL BENEFICIATION AND TRANSPORT

Altex Technologies Corporation 650 Nuttman Road, #114 Santa Clara, CA 95054	Reconstitution of Beneficiated Coal Using the Biobinder Process
Clarke Rajchel Engineering P.O. Box 5128 Arvada, CO 80005	A High-Quality Coal Water Slurry Production Process

TOPIC: ADVANCED TECHNOLOGY FOR THE RECOVERY, STORAGE, AND UTILIZATION OF NATURAL GAS

Advanced Resources International, Inc. 165 South Union Boulevard, Suite 816 Lakewood, CO 80228	Development of an Exploration Strategy Designed for Identifying Regions Capable of High Gas Utilizing the Open-Hole Cavitation Technique

Bend Research, Inc. 64550 Research Road Bend, OR 97701-8599	A Novel Process for the Removal of Nitrogen from Nitrogen-Containing Natural Gas: Development of Water-Based Absorbents
Eltron Research, Inc. 2830 Wilderness Place, Suite E Boulder, CO 80301-5455	Natural Gas Conversion to Ethylene in Intermediate Temperature Fuel Cells
Engineering Resources, Inc. P.O. Box 3682 Fayetteville, AR 72702	Biological Production of Sulfur from Hydrogen Sulfide
Engineering Resources, Inc. P.O. Box 3682 Fayetteville, AR 72702	Biological Removal of Coal Mine Methane
Northwest Fuel Development, Inc. 4064 Orchard Drive Lake Oswego, OR 97035	A Pressure Swing Adsorption/Temperature Swing Adsorption Process for Nitrogen Rejection from Natural Gas
Structured Materials Industries, Inc. Enterprise Development Center 240 Martin Luther King Boulevard Newark, NJ 07102	Development of Long Wavelength Infrared Detectors for Trace Gas Detection

TOPIC: COAL-BASED POWER SYSTEMS TECHNOLOGY

Energy Research Corporation 3 Great Pasture Road Danbury, CT 06813	A Carbonate Fuel Cell Monolith for Low-Cost and High Power Density Operation
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06813	Advanced Ceramic Fibers for a Carbonate Fuel Cell Matrix
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06813	An Improved Carbonate Fuel Cell Design

Manufacturing and Technology Conversion International, Inc. P.O. Box 21 Columbia, MD 21045	An Innovative Clean High Temperature Air Heater (HTAH) for Coal-Fired Gas Turbines

TOPIC: ENHANCED OIL RECOVERY

Insitec, Inc. 2110 Omega Road, Suite D San Ramon, CA 94583	Optimization of Recovery and Contamination Minimization for Oil Production Water
Justice Associates, Inc. P.O. Box 985 Addison, TX 75001-0985	A Geostatistical Analysis of Crossborehole Seismic Data for Reservoir Characterization
K&A Energy Consultants, Inc. 6849 East 13th Street Tulsa, OK 74112	Transporting Mobility Control Agents to High Permeability Thief Zones

TOPIC: ADVANCED FOSSIL RESOURCE UTILIZATION

Advanced Fuel Research, Inc. P.O. Box 380379 East Hartford, CT 06138-0379	A Complete Combustion Analysis Using a Combination Fourier Transform-Infrared/Fourier Transform-Raman Spectrometer
Advanced Materials Corporation 100 North Bellefield Avenue Bellefield Towers 861 Pittsburgh, PA 15213	Design and Construction of a Novel High Force Magnetic Separator
Illimite, Inc. P.O. Box 18529 Rochester, NY 14618-0529	An Optical Methanometer for the Remote Detection of Methane Gas in Hazardous Areas
Praxis Engineers, Inc. 852 North Hillview Drive Milpitas, CA 95035	Use of Supervisory Control Techniques for Optimization of Environmental Emissions in Power Plants

TOPIC: CLIMATE CONTROL TECHNOLOGIES FOR TRANSPORTATION SYSTEMS

Creare, Inc. P.O. Box 71 Hanover, NH 03755	**A Waste Heat Powered Stirling Truck Refrigerator**
INSTATHERM Company 101-B Woodwinds Industrial Court Cary, NC 27511	**A Small High Rate Thermal Storage System for Electric Vehicles**
Rocky Research 1598 Foothill Drive P.O. Box 61800 Boulder City, NV 89006-1800	**An Engine Exhaust Fired Non-Chlorofluorocarbon Refrigeration and Thermal Storage System**
Solar Car Corporation 1300 Lake Washington Road Melbourne, FL 32904	**An Electric Vehicle Climate Control System Using Vapor Compression for Heating and Cooling**

TOPIC: CHEMICAL PRODUCTS FROM BIOMASS

Advanced Fuel Research, Inc. P.O. Box 380379 East Hartford, CT 06138-0379	**Production of Carbon Materials from Biomass**
Decamp Industries, Inc. 1062 Bluestem Lane Batavia, IL 60510-3304	**Oxygenated Gasoline Extenders from Renewable Resources**
Metabolix, Inc. P.O. Box 695 Cambridge, MA 02142	**Enzyme Catalyzed Polymerization of Chiral Acids in Organic Solvents**

TOPIC: BIOMASS ELECTRIC POWER TECHNOLOGY

LSR Technologies, Inc. 898 Main Street Acton, MA 01720	**A Novel Hot Gas Cleanup System for Biomass Power Technology**

TOPIC: ADVANCED WINDOW AND GLAZING TECHNOLOGIES

Aerodyne Research, Inc. 45 Manning Road Billerica, MA 01821	An In-Situ Tester for Seal Integrity of Multiple Pane Windows
Ashwin-Ushas Corporation, Inc. 206 Ticonderoga Boulevard Freehold, NJ 07728	Flexible Electrochromic Window Materials Based on Poly (Diphenyl Amine) and Related Conducting Polymers
Creare, Inc. P.O. Box 71 Hanover, NH 03755	A High Performance Window Edge and Frame Design
EIC Laboratories, Inc. 111 Downey Street Norwood, MA 02062	Electrochromic Glazings Deposited by High Rate Processes
Gumbs Associates, Inc. 11 Harts Lane East Brunswick, NJ 08816	Development of Advanced Window Materials Based on Conducting Polymer/Sol-Gel Ceramic Composites
Meyer and Lonberg Association 70 Buckminster Road Brookline, MA 02146	Liquid Crystal Smart Windows
Physical Optics Corporation 20600 Gramercy Place, Suite 103 Torrance, CA 90501	Novel Spectrally Selective Window Films Based on Multiplexed Holography
SAGE Corporation 704 Executive Boulevard Valley Cottage, NY 10989	The Feasibility of Using Squeeze Roll Coating to Form Sol-Gel Derived Layers for Switchable Electrochromic Windows

TOPIC: EDUCATIONAL TECHNOLOGIES

ADA Technologies, Inc. 304 Inverness Way South, Suite 110 Englewood, CO 80112	A Laboratory/Field Workstation for Science Education

Advanced Fuel Research, Inc. PO Box 380379 East Hartford, CT 06138-0379	Interactive Computer Simulations to Demonstrate the Behavior of Gases, Liquids, and Solids on an Atomic and Molecular Basis
Owen Research 2525 Arapahoe Avenue, Suite E4-262 Boulder, CO 80302-6720	An Intelligent Tutor to Advance Integrated Mathematics Curricula in Middle and Secondary Schools
Ross Computational Resources 318 North Franklin Avenue Madison, WI 53705	EarthLab: A Televisualization Environment for Learning Through Cooperative Problem Solving in Earth Science Education
Statistical Sciences, Inc. 1700 Westlake Avenue North, Suite 500 Seattle, WA 98109	An Intelligent Tutoring System for Statistics
Videodiscovery, Inc. 1700 Westlake Avenue North, Suite 600 Seattle, WA 98109	Living On Earth: A Multimedia-Based Learning Environment for the Earth Sciences
W.W. Gaertner Research, Inc. Gaertner Building 140 Water Street Norwalk, CT 06854	A Virtual Environment Workstation for Energy Education

TOPIC: HUMAN GENOME

Chromex, Inc. 2705-B Pan American Freeway, N.E. Albuquerque, NM 87107	A High Spatial Resolution Spectrograph for DNA Sequencing
Collaborative Research, Inc. 1365 Main Street Waltham, MA 02154	Non-Radioactive Detection Systems Based on Enzyme Fragment Complementation
Paralogic, Inc. 115 Research Drive Bethlehem, PA 18015-4734	High Performance Searching and Pattern Recognition for Human Genome Databases

Soane Technologies, Inc. 3916 Trust Way Hayward, CA 94545	Separation Media for DNA Sequencing

TOPIC: BIOTECHNOLOGY: STRUCTURAL BIOLOGY AND MOLECULAR NUCLEAR MEDICINE

Diatech, Inc. 9 Delta Drive Londonderry, NH 03053	Technetium-Radiolabeled Somatostatin Receptor Binding Peptides for Imaging Certain Cancers
InterFET Corporation/RMD, Inc. 44 Hunt Street Watertown, MA 02172	A Novel Detector for X-Ray Absorption Spectroscopy

TOPIC: INSTRUMENTATION FOR OCEAN MEASUREMENTS

Owen Research 2525 Arapahoe Avenue, Suite E4-262 Boulder, CO 80302-6720	An Automated and Submersible Optical Sensor for Very-Near Bottom Momentum Characterization
RD Instruments 9855 Businesspark Avenue San Diego, CA 92131	Bistatic Acoustic Turbulence and a Suspended Sediment Profiler
Umpqua Research Company P.O. Box 791 Myrtle Creek, OR 97457	An Oceanographic Carbon Dioxide Sensor

TOPIC: DESIGN AND APPLICATIONS OF NOVEL MATERIALS

Advanced Fuel Research, Inc. P. O. Box 380379 East Hartford, CT 06138-0379	On-Chip Ferroelectric Energy Storage Capacitors for Silicon Solar Cells
Advanced Refractory Technologies, Inc. 699 Hertel Avenue Buffalo, NY 14207	Porous Aluminum Nitride Part Fabrication to Support Advanced Battery Development

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American Superconductor Corporation 149 Grove Street Watertown, MA 02172	Oxide Dispersion Strengthened Silver for Use in High-Temperature Superconductor Composite Wires
COM:ONE 1526 Elka Avenue San Jose, CA 95129	Fabrication of Silicon Carbide Structures of Arbitrary Shape
Chemat Technology, Inc. 19441 Business Center Drive, #139 Northridge, CA 91324	Capacitive Energy Storage Using High Surface Area Transition Metal Compounds
Colorado Engineering Research Laboratory, Inc. 1500 Teakwood Court Fort Collins, CO 80525	Lubricious-Surface Silicon-Nitride Rings for High-Temperature Tribological Applications
GINER, Inc. 14 Spring Street Waltham, MA 02154-4497	Molded Titanium Carbide Bipolar Plates for High Voltage Battery and Fuel Power Sources
ISM Technologies, Inc. 9965 Carroll Canyon Road San Diego, CA 92131	Low Temperature Deposition of Titanium Nitride
Ibis Technology Corporation 32A Cherry Hill Drive Danvers, MA 01923	Room Temperature Photoluminescence of Germanium Nanostructures by High Energy Implantation of Germanium into a Buried Oxide of Silicon
Interphases Research 722 Rushing Creek Place Thousand Oaks, CA 91360	Nanoscale Processing for Ternary Semiconductors
Jet Process Corporation 25 Science Park New Haven, CT 06511	Jet Vapor Deposition of Ultra-thin Platinum Catalyst Loadings Directly on Polymer Ion-Exchange Membranes for Fuel Cell Applications

New Material Concepts 15 Guile Avenue Tewksbury, MA 01876	A Direct Thermal to Optical Energy Converter
Spire Corporation One Patriots Park Bedford, MA 01730-2396	Quantum Confinement Effects in Heteroepitaxial Silicon/Zinc Sulfide Nanostructures Produced by Metallo-Organic Chemical Vapor Deposition
Ultramet 12173 Montague Street Pacoima CA 91331	Coated Micrograin Carbides for Wear Resistance

TOPIC: ADVANCED GEOPHYSICAL IMAGING IN GEOSCIENCES RESEARCH

A.J. Devaney Associates, Inc. 355 Boylston Street Boston, MA 02166	Detection and Parameter Estimation from Electromagnetic Scattering Data in Offset/Reverse Vertical Seismic Profile Geometrics
Multi Spectrum Technologies, Inc. 914 Arizona Avenue, Suite 1 Santa Monica, CA 90401	Vertical Seismic Profiling: Spectrum Offset Inversion
Radix Systems, Inc. 6 Taft Court Rockville, MD 20850	An Experimental Evaluation of Chaotic Waveforms for Crosswell Seismic Tomography

TOPIC: CHEMICAL SCIENCES RESEARCH

Advanced Fuel Research, Inc. P.O. Box 380379 East Hartford, CT 06138-0379	On-Chip Infrared-Spectral Sensors by Superconducting Detector Arrays
Bend Research, Inc. 64550 Research Road Bend, OR 97701-8599	Composite Plasma-Polymer Membranes

Ciencia, Inc. 111 Roberts Street, Suite C East Hartford, CT 06108	On-Line Micro-Sensors for Analytical Chemical Measurement
Energy and Environmental Research Corporation P.O. Box 189 Whitehouse, NJ 08888	Multiple Air Pollutant Emissions Removal by the Use of a Single Chemical Additive
Membrane Technology and Research, Inc. 1360 Willow Road, Suite 103 Menlo Park, CA 94025	Solid Polymer Electrolyte Membranes for Olefin Separation
Physical Sciences, Inc. 20 New England Business Center Andover, MA 01810	Time Resolved Nitric Oxide Measurements in Combustion Exhausts
REB Research and Consulting 811 Oak Street East Lansing, MI 48823	Improved Coated-Metal Hydrogen Extraction Membranes
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	Zeolite Membranes for Gas Separations

TOPIC: MATERIALS SCIENCES INSTRUMENTATION

Advanced Fuel Research, Inc. P.O. Box 380379 East Hartford, CT 06138-0379	An In-Situ Particle Sensor for Metal Forming Processes
Advanced Optical Technologies, Inc. 628 Hebron Avenue Glastonbury Corporate Center, Building 2 Glastonbury, CT 06033-2495	A High Count Rate Two-Dimensional Neutron Detector
Advanced Research and Applications Corporation 425 Lakeside Drive Sunnyvale, CA 94086	A Wavelength Dispersive Spectrometer for Analytical Electron Microscopy

BioTraces, Inc. 7986 Lakecrest Drive Greenbelt, MD 20770	Development of a High Spatial Resolution Neutron Detector
Nanoptics, Inc. 3014 Northeast 21st Way Gainesville, FL 32609	A High Resolution Scintillator-Based Neutron Detector

TOPIC: HIGH PERFORMANCE COMPUTING RESEARCH

Aware, Inc. One Memorial Drive Cambridge, MA 02142	Parallel Wavelet Methods for Computational Fluid Dynamics
Q-Chem, Inc. 7520 Graymore Road Pittsburgh, PA 15221	A Rapid Calculation of the Coulomb Field in Large Molecules

TOPIC: TECHNOLOGY FOR THE SUPERCONDUCTING SUPER COLLIDER

Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523	A Simple, Superconducting Elementary-Charge Polarity Detector
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545	Fabrication of a Superconducting Super Collider Dipole Magnet Bore Tube Liner from Copper-Niobium Nanocomposite Produced by Mechanical Alloying

TOPIC: TECHNOLOGY AND INSTRUMENTATION FOR HIGH ENERGY ACCELERATORS

Creare, Inc. P.O. Box 71 Hanover, NH 03755	A High-Performance Cryogenic Heat Exchanger
Creare, Inc. P.O. Box 71 Hanover, NH 03755	Reliable Centrifugal Machines for Helium Circulation in Cryogenic Refrigerators

DULY Research, Inc. 1912 MacArthur Street Rancho Palos Verdes, CA 90732	A Microwave Power Combiner for a Cluster Klystron
FM Technologies, Inc. 10529-B Braddock Road Fairfax, VA 22032	An Efficient 10-20 Gigahertz High-Power Microwave Amplifier
Haimson Research Corporation 4151 Middlefield Road Palo Alto, CA 94303-4793	A 17 Gigahertz High-Gradient Accelerator Structure for a Compact 30 MeV, Picosecond Bunch Electron Source
IGC Advanced Superconductors, Inc. 1875 Thomaston Avenue Waterbury, CT 06704	Thermo-Mechanical Processing of Niobium Titanium Based Superconductors
Integrated Applied Physics, Inc. 261 North San Gabriel Boulevard P.O. Box 70166 Pasadena, CA 91117-7166	A High Current, High Brightness Ferroelectric Electron Source for Advanced Accelerator Applications
Lightwave Electronics Corporation 1161 San Antonio Road Mountain View, CA 94043	A Mode-Locked Pulse Pre-Amplifier for Photocathode Illumination
MDS Company 1955 Mountain Boulevard, Suite 101 Oakland, CA 94611	Development of a 100 Megawatt X-Band Relativistic Klystron Amplifier
Mission Research Corporation 735 State Street P.O. Drawer 719 Santa Barbara, CA 93102-0719	Magnetron Arrays for Linear Colliders
Omega-P, Inc. 2008 Yale Station New Haven, CT 06520	A Modified Inverse Free-Electron-Laser Accelerator
Spire Corporation One Patriots Park Bedford, MA 01730-2396	Improved Sources of Spin-Polarized Electrons

TOPIC: HIGH ENERGY PHYSICS DATA PROCESSING AND DETECTOR INSTRUMENTATION

Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523	Compact, High-Density Analog/Digital Readout Circuits for Silicon Microstrip Detector Arrays

TOPIC: NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

Advanced Research and Applications Corporation 425 Lakeside Drive Sunnyvale, CA 94086	Monolithically Integrated Detector Arrays
Advanced Technology Materials, Inc. 7 Commerce Drive Danbury, CT 06810	Diamond-Based Photomultipliers
Conductus, Inc. 969 West Maude Avenue Sunnyvale, CA 94086	A Superconducting Time Interpolator for Nuclear Physics Instrumentation
Detectronics 2517 Regent Road Livermore, CA 94550	Gallium Arsenide Pixel and Microstrip Detectors

TOPIC: ACCELERATOR TECHNOLOGY FOR NUCLEAR PHYSICS

AccSys Technology, Inc. 1177A Quarry Lane Pleasanton, CA 94566	An Extended Interdigital Niobium Superconducting Linac Structure for Low Velocity Heavy Ions
Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523	A 100 Gigahertz Acquisition of Bunch Profile, Position, and Arrival Time for Particle Accelerator Diagnostics and Control
Quantum Magnetics, Inc. 11578 Sorrento Valley Road San Diego, CA 92121	An Intensity and Position Monitor for Particle Beam Diagnostics

TOPIC: SPECIAL INSTRUMENTATION FOR NUCLEAR CROSS SECTION MEASUREMENTS

Charles Evans and Associates 301 Chesapeake Drive Redwood City, CA 94063	A High Resolution Multistop Time-to-Digital Converter

TOPIC: PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

Applied Sciences, Inc. 141 West Xenia Avenue P.O. Box 579 Cedarville, OH 45314	A Vapor-Grown, Carbon Fiber-Reinforced Beryllium Composite for Plasma Facing Material
Composite Technology Development, Inc. 2400 Central Avenue, Suite H Boulder, CO 80301	Radiation Resistant Radio Frequency Feedthrough Insulators for Fusion Applications
Creare, Inc. P.O. Box 71 Hanover, NH 03755	Helium-Cooled Divertors with Low-Activation Materials and Simple Fabrication Techniques
IGC Advanced Superconductors, Inc. 1875 Thomaston Avenue Waterbury, CT 06704	Methods of Improving Internal-Tin Niobium-Tin for Fusion Applications
Karta Technology, Inc. 1892 Grandstand San Antonio, TX 78238	Advanced Ultrasonic Methods for the Nondestructive Evaluation of Bond Quality in Brazed Composite-Metal Joints
Lodestar Research Corporation 2400 Central Avenue, P-5 Boulder, CO 80301	Ponderomotive Feedback Stabilization for Control of External Kink Modes and Disruptions in Tokamaks
Nuclear and Aerospace Materials, Inc. 16716 Martincoit Road Poway, CA 92064	High Thermal Conductivity Graphite for the International Thermonuclear Experimental Reactor First Wall

DOE/ER-0599 . . ABSTRACTS OF 1993 PHASE I AWARDS -- SBIR PROGRAM NOVEMBER 1993

DOE/ER-0599

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE I AWARDS

1993

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager
Washington, D.C. 20585

DOE/ER-0599

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE I AWARDS

1993

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager
Washington, D.C. 20585

PREFACE

The Federal SBIR Program

This program, now completing its eleventh year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Eleven Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over $100 million. The agencies were required to set aside 1.5% of those budgets in Fiscal Year (FY) 1993 to fund SBIR projects. (This amounted to about $50 million in FY 1993 for the Department of Energy.) Each agency solicits proposals from small science- and technology-based US firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to $50,000 in FY 1992. Phase II is the principal research or R&D effort, and the awards were as high as $500,000 in FY 1993 for work to be performed in a period of up to two years. Phase III is the commercial application of the research or R&D effort by the small businesses using non-Federal funding or, alternatively, it may involve follow-on non-SBIR Federal contracts for products or services desired by the Government. The program continues to strengthen the role that small, innovative firms play in meeting the Nation's research and development needs and in commercialization of ideas developed through federally funded R&D.

Phase I Awards for FY 1993

Contained in this booklet are abstracts of the Phase I awards made in FY 1993 under the DOE SBIR program. The 168 Phase I projects described here were selected in a highly competitive process from a total of 1,999 grant applications received in response to the 1993 DOE annual SBIR Solicitation. The selections for awards were made on scientific and technical merit, as judged against the specific criteria listed in the Solicitation. Conclusions were reached on the basis of detailed reports returned by reviewers drawn from DOE laboratories, universities, private industry, and government. (Any discrepancies noted in prior DOE releases naming the firms selected for awards are due either to the firm changing its name after the award selection or to the firm not proceeding to a signed grant.) It is expected that between one-third and one-half of the Phase I projects will be continued into Phase II.

The work described in the abstracts is novel, high-risk research, but the benefits will also be potentially high if the objectives are met. Brief comments on the potential applications, as described by the awardee, are given after each abstract. Individuals and organizations, including venture capital and larger industrial firms, with an interest in the research described in any of the abstracts are encouraged to contact the appropriate small business directly.

The DOE SBIR Program

DOE's FY 1993 annual Solicitation contained 37 technical topics in the areas of basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, energy efficiency and renewable energy, fossil energy, nuclear energy, and environment, safety, and health. There is keen competition because awards are made solely on the basis of scientific and technical merit, regardless of the technical topic.

As a measure of the program's success, ten DOE SBIR projects have received R&D-100 Awards from Research and Development Magazine, which selects the 100 most significant technical products each year. In addition, five DOE awardees were chosen among the 500 fastest-growing American private companies, in the December 1991 issue of Inc. Magazine, based on their growth in sales. Also, from the first five cycles of awards (Phase II projects completed between 1986 and 1990), DOE SBIR winners have already received over $230 million in Phase III funding, which is more than 50% larger than the SBIR support they were given. This number is expected to grow significantly in the next few years.

The DOE SBIR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. In the first year of Phase II awards (1984), a system was devised and implemented that allowed Phase I awardees who felt they were ready to submit their Phase II proposals before their Phase I grants ended, to do so. For each of the ten years in which Phase II awards have been made, such grantees who were chosen for Phase II funding were able to begin their projects without an interruption in funding. Since 1984, about 40 per cent of the Phase II awardees have had continuous funding between Phases I and II.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, DOE has instituted a special training project, supported by non-SBIR funds. For the past four years, successful Phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participation in the 1991 project, the SBIR companies have already received more than $5.5 million for commercialization of their SBIR research with a projected royalty stream from option agreements of an additional $24 million over the next five years. About 43% of the firms that completed the project have received further funding for their work.

The SBIR program enables DOE to obtain effective, innovative solutions to important problems through the private sector, which has a commercial incentive to pursue the resulting technology and bring it to the marketplace. The growing number of awardees, many of them started in business in response to SBIR solicitations, is becoming a significant resource for the solution of high risk, high technology problems for the Department.

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ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY FOR FOSSIL ENERGY

1

An Innovative Continuous Emissions Monitor for Air Toxic Metals--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Dr. David E. Hyatt, Principal Investigator
Dr. Judith A. Armstrong, Business Official
DOE Grant No. DE-FG02-93ER81498
Amount: $73,967

The Clean Air Act (CAA) amendments of 1990 defined 189 individual hazardous air pollutants which must be monitored and controlled. This list of air toxics contains 11 inorganic (metal) constituents and includes arsenic, beryllium, mercury, antimony, cadmium, chromium, cobalt, lead, manganese, nickel, and selenium. Current technology for measuring these components in emission streams depends upon extraction of a sample from the stack followed by analysis for the metals of interest with a separate analytical procedure. This project describes the development of a novel continuous emissions monitor (CEM) for air toxic metals. It will develop the foundation for extending the technology of plasma emission spectroscopy into the new area of immediate analysis of air toxic metal species. This technique provides the basis for direct simultaneous monitoring of part per billion levels of several toxic species in flue gas. Phase I begins with assembly of a laboratory instrument followed by measurement of the emission characteristics of air toxic metal species in flue gas mixtures with this instrument. The successfully demonstrated Phase I system will provide the design basis and identify critical elements in the Phase II prototype instrument which will be tested at actual plant sites. Successful completion of Phases I and II will underlie Phase III commercialization of the analyzer.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful development of the proposed technology through the Phase I and II stages should result in a new generation for CEMs for the suite of air toxic metals set forth in the CAA with an accuracy and precision previously unattainable. Markets for the instrument include thousands of individual coal-fired power plants, incinerators, industrial boilers, process industry plants, minerals processing and smelting facilities, refineries, metal fabrication shops, and other thermal processing sites.

2

Non-Toxic Additives for Improved Fabric Filter Performance--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Ms. C. Jean Bustard, Principal Investigator
Dr. Judith A. Armstrong, Business Official
DOE Grant No. DE-FG02-93ER81500
Amount: $74,963

Improved fabric filter performance for both the collection of fine particulate matter (particles less than 10 microns) and toxic metal emissions from flue gases is important because most of the toxic metals are concentrated in this size range, fine particles are respirable and therefore pose a health risk, and fine particles are effective light scatterers and lead to high opacity levels. It is planned in Phase I to demonstrate that novel flue gas conditioning products can improve fine particle collection efficiency and overall performance of fabric filters. New flue gas conditioning additives for fabric filters will be evaluated in the laboratory using a flue gas simulator and a filter test device (FTD). The FTD uses short sections of full-scale bags and has proven to be effective in comparison with both pilot- and full-scale fabric filters. The candidate additives are both cost effective and non-toxic. Successful demonstration of these additives will increase the number of additive choices presently available to fabric filter users and will represent a significant cost savings over the methods presently in use. Additives that proved to be successful in Phase I will be evaluated at a full-scale utility power plant in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: Flue gas conditioning can improve fine particle collection and pressure drop performance of fabric filters. Successful demonstration of new flue gas conditioning additives will provide state-of-the-art additives that are cost effective and non-toxic. These flue gas conditioning technologies will be applicable, not only to more than 115 utility power plant fabric filters, but to fabric filters on incinerators, industrial boilers, process industries, minerals processing and smelting facilities, refineries, metal fabrication shops, and other thermal processing sites.

3

Real-Time Continuous Analysis of Total and Elemental Mercury--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Mr. Richard J. Schlager, Principal Investigator
Dr. Judith A. Armstrong, Business Official
DOE Grant No. DE-FG02-93ER81501
Amount: $74,615

Stationary sources in the U.S. emit about one million kg of mercury into the atmosphere annually. Major sources of these emissions are fossil fuel combustion facilities and municipal solid waste incinerators. Much work is being done by DOE and industry to characterize these emissions and to develop effective control measures. Continuous emissions monitors (CEMs) for mercury will play a significant role in quickly advancing the level of understanding and control of mercury emissions. Unfortunately, existing CEMs are capable of measuring only the elemental form of mercury, and do not account for speciated mercury compounds adequately. Phase I outlines a plan for developing a technology for converting speciated mercury compounds to the elemental form for measurement using CEMs. A successfully developed system will allow a mercury CEM to be used to continuously monitor elemental mercury emissions, total mercury emissions, and (by difference) total speciated mercury emissions from stationary sources. A successful Phase I project will be expanded in Phase II where a converter will be fabricated for use with a mercury CEM. The Phase II monitoring system for total mercury will be evaluated and validated at several stationary sources.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful development of the proposed mercury conversion system will allow for the use of available CEMs for the real-time monitoring and control of total mercury emissions from stationary sources. Mercury emissions will be reduced to a greater extent and these reductions will be verifiable as a result of a successful program. Mercury control will be more effective when CEMs are used to measure these emissions.

4

Removal of Volatile Metals from High Temperature Coal Conversion Gas Streams--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Mr. Richard J. Schlager, Principal Investigator
Dr. Judith A. Armstrong, Business Official
DOE Grant No. DE-FG03-93ER81499
Amount: $74,845

DOE is developing a number of advanced coal conversion processes that operate at high temperatures and pressures. The coal that is converted in these processes produces a variety of contaminants. These contaminants need to be removed from the hot gas stream in order for the process to operate at maximum efficiency. Volatile metals constitute a family of compounds found in these gas streams that will require removal not only to protect downstream equipment from corrosion, but in order to meet expected future environmental control regulations. The development of sorbents to remove volatile metal emissions at high temperatures from these systems is the objective of this project. Twelve candidate sorbents will be evaluated during Phase I laboratory testing at high temperature using a gas stream simulating an actual coal conversion stream. Mercury will be used as a surrogate volatile metal for the tests. Reacted sorbents will be subjected to a comprehensive series of analytical tests to determine the fundamental mechanisms involved in capturing the mercury. Data to be obtained include absorptive capacities, sorption capabilities as a function of temperature and residence time, reaction product composition, reaction sites, and reacted sorbent stability. Selected sorbents will be evaluated further during Phase II to evaluate physical treatments (pelletizing), and long term stability.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful development of high temperature metal removal sorbents will help to advance coal conversion processes and will help maintain a clean environment. Any operation utilizing coal or oil would benefit from the developments of this program.

5

An Instrument for In-Situ Analysis of Carbon in Fly Ash--Advanced Fuel Research, Inc., P. O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. Anthony S. Bonanno, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG05-93ER81509
Amount: $74,977

An instrument capable of making on-line, in-situ measurements of residual carbon content in fly ash would be a valuable asset in the optimization of power plant efficiency and in achieving pollution control goals. Current instruments available to measure residual carbon in fly ash are based on extractive point samples. Measurements of this type are relatively slow, are prone to inaccuracies, and require significant maintenance and sample handling instrumentation. Preliminary measurements indicate that the infrared spectral emissivity of fly ash particles is correlated to residual carbon content. A detailed study of this correlation will be undertaken in Phase I in order to develop an infrared emissivity-based monitor capable of making on-line, in-situ measurements of carbon in fly ash in coal combustion facilities. Phase I will include both laboratory-scale and pilot plant tests of the method, and specifications will be made for a prototype carbon in fly ash monitor to be constructed in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: An instrument to measure on-line the carbon in fly ash would allow the development of control technology to improve the efficiency and environmental acceptability of coal-burning power plants. The measurement of carbon in fly ash by a Fourier transform infrared instrument could be coupled with on-line measurements, using the same instrument, of other pollutants such as carbon monoxide, hydrogen chloride, nitrogen and sulfur oxides, and hydrocarbons. Such an instrument would provide all the data required for complete optimization of the combustion process.

6

Oxide Based Ceramic Composite Hot Gas Filter Development--Ceramic Composites, Inc., 1110 Benfield Boulevard, Millersville, MD 21108; (410) 987-3435
Mr. E. L. "Ted" Paquette, Principal Investigator
Mrs. Sharon Fehrenbacher, Business Official
DOE Grant No. DE-FG05-93ER81520
Amount: $74,715

Hot gas particulate filtration is critical to nearly every clean coal energy conversion technology. To date, ceramic filters have exhibited limited life and reliability because of thermal shock, thermal stress, and corrosion reactions with coal ash constituents. Oxide fiber-oxide matrix ceramic composites are excellent candidates as hot gas filters. They possess far superior toughness and mechanical strength properties than porous monolithic ceramic filters. The selection of oxide constituents will provide the highest corrosion resistance against coal combustion and gasification byproducts. Oxide-oxide composite filter samples in tubular geometry will be developed in Phase I using low cost preform fabrication techniques based on chemical vapor infiltrated boron nitride interfaces and oxide matrices of alumina and zirconia. The oxide-oxide composite filter structures will be tested for coal particulate filtration efficiency and durability. Post test microstructural and chemical analyses will provide guidance for composite processing improvements and scale-up in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: Hot gas particulate filtration is a key technology for most clean coal energy conversion technologies. By demonstrating effective long life, reliable hot gas filters with reasonable pressure drop characteristics, many clean coal programs will move a full step closer to pilot plant and full size commercial plant demonstration. Most industrial processes such as vapor phase production of titanium dioxide pigments, carbon blacks, cements, and iron oxides are performed in ways that intentionally avoid the need for hot gas filtration. The existence of proven, effective hot gas filtration systems may encourage the development of new processes that use hot gas filtration and permit hot process gases to be recycled or used in thermodynamically efficient energy recovery systems.

7

Direct Sulfur Reduction in Advanced Coal Conversion Processes--Core Technologies, Inc., P.O. Box 1744, Tacoma, WA 98401; (206) 272-1636
Mr. Bruce A. McFadden, Principal Investigator
Dr. F. Paul Carlson, Business Official
DOE Grant No. DE-FG03-93ER81561
Amount: $75,000

Elimination of sulfur contaminants from hot coal gas and their subsequent reduction or disposal is an essential step for the viable application of advanced coal conversion technologies, such as integrated gasification combined cycle systems. Mixed metal oxide sorbent beds have been shown to be very effective for hot fuel gas cleanup with overall sulfur removal efficiencies exceeding 95%. Hot off gas resulting from sorbent bed regeneration contains, depending on the process, from 1 to 12 % sulfur dioxide, which is then preferentially converted to an economically usable form. Since elemental sulfur is easily handled, has a large market, and presents no sludge disposal problem, cost-effective direct sulfur reduction processes (DSRP) are being investigated. The research covered by this project is to determine whether a new electrodeless radio frequency plasma system described as plasma electron dissociation (PED) would be a viable DSRP to be used in conjunction with mixed metal oxide systems to produce elemental sulfur from the hot regeneration off gas. Planned work in Phase I includes conducting tests with simulated gas input to evaluate operating performance (e.g., conversion rate vs. throughput), estimate operating costs, and project capital costs for scaled-up systems. The project will include testing a computer model of the plasma operation and validating it with experimental data.

Anticipated Results / Potential Commercial Applications as described by the awardee: The anticipated results could show that the plasma system can be a cost effective method for direct reduction of sulfur dioxide at high conversion rates, particularly with more concentrated off-gas streams. Very rapid reaction speeds, responsiveness, and easily controlled power input should permit a compact system with excellent performance and control characteristics. Furthermore, limited tests will be conducted to demonstrate its flexibility to reduce other pollutants, particularly nitrogen oxides. The goal of this research is to demonstrate that this technology is a viable new alternative for controlling fuel gas pollutants in advanced coal conversion processes.

8

An Evaluation of Two Pelletized Coal Fly Ashes as Substrates for Subsurface Flow Wetland Wastewater Treatment Systems--DB Environmental Laboratories, Inc., 414 Richard Road, Suite 1, Rockledge, FL 32955; (407) 639-4896
Dr. Forrest E. Dierberg, Principal Investigator
Mr. Thomas A. DeBusk, Business Official
DOE Grant No. DE-FG05-93ER81505
Amount: $72,130

The use of pelletized, stabilized fly ash will be investigated as a substrate to enhance phosphorus (P) removal from wastewater effluents in subsurface flow (SF) emergent plant-based wetlands. The following experiments are being conducted in Phase I to demonstrate the feasibility of using fly ash pellets as a substrate in constructed wetlands for removing P: (1) P adsorption/desorption isotherms for two sizes of each of two types of stabilized fly ash pellets; (2) screening of three emergent macrophyte species rooted in two types of stabilized fly ash for relative toxicity or inhibitory effects on growth, morphology, and foliage-to-rhizosphere oxygen transport; (3) greenhouse study of P removal from a continuous flow of municipal sewage effluent using SF wetland microcosms containing one macrophyte species rooted in stabilized fly ash pellets; (4) potential leaching of boron, fluorine, arsenic, selenium, cooper, chromium, nickel, and molybdenum from stabilized fly ash pellets from the SF wetland microcosms during nine weeks of exposure to sewage effluent; (5) hydraulic conductivity of the SF wetland fly ash substrate before and after nine weeks of inundation; and (6) P and trace element uptake by root, rhizome, and shoot portions of the emergent macrophytes cultured in the SF wetland microcosms.

Anticipated Results / Potential Commercial Applications as described by the awardee: SF treatment wetlands with stabilized coal fly ash pellets as the substrate may prove to be cost-effective systems for removing P from wastewaters prior to discharge. Design, construction, and operation of SF wetland systems for use by municipalities, industries, and agriculture for treating effluent wastewater streams, process waters, and stormwater runoff are promising commercial applications.

9

A Method for the Reduction of Dust Cake Adhesion in Ceramic Filter Systems--Industrial Filter and Pump Manufacturing Company, 5900 Ogden Avenue, Cicero, IL 60650; (708) 656-7800
Mr. Paul Eggerstedt, Principal Investigator
Mr. Paul Eggerstedt, Business Official
DOE Grant No. DE-FG02-93ER81519
Amount: $75,000

Ceramic filtration is one of the most cost effective and promising technologies for removing particulates at high temperatures to levels exceeding New Source Performance Standards (NSPS) as well as Clean Air Act mandates. With submicron retention capabilities, ceramic filters are ideally suited for virtually complete particulate and spent sorbent capture in pressurized fluidized bed combustion and coal gasification systems. Unfortunately, however, such coal conversion processes can produce cohesive particulates, because of the presence of tars, condensibles, or fused ash, often caused by temperature transients. With on-line jet pulse cleaning as the only means by which particulates are dislodged from a candle filter, such conditions can quickly create cementitious formations which tend to "blind" the filtering surface irreversibly; under severe conditions, this can result in complete destruction of the filter components. Fortunately, a method to reduce pore blinding and adhesion of such dust cakes collected on ceramic filters exists through utilization of boron nitride. Stable in both oxidizing and reducing atmospheres at temperatures of up to 2000°F, boron nitride is commercially used as a high temperature dry lubricant. Phase I objectives include efforts to investigate application techniques of boron nitride to commercially available silicon carbide and aluminosilicate fiber filters, as well as to investigate the fabrication of a monolithic boron nitride filter candle. Comparative testing of the boron nitride coated elements with untreated elements will be conducted to determine any permeability changes and the extent of dust cake adhesion reduction, using both coal gasification and coal combustor dust sources, in an existing test rig; the monolithic boron nitride filter candle will undergo similar testing as well as strength evaluations, for comparison with commercially available filter elements.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase I results should show that treatment of commercially available filter elements with a boron nitride suspension and the formation of a completely monolithic boron nitride filter element will provide properties within the pore structure of ceramic filter elements to prevent or reduce the degree of pore blinding and dust adhesion. Phase II should show how such filter elements function with respect to reduced dust cake adhesion, at high temperature. Commercially, these filter elements will feature reduced pressure differentials, down time, and related costs, with increased cleanability and overall performance, especially during periods of changing temperature or dust characteristics.

10

Innovative Silicon Carbide Fiber Composite Filters--Materials and Electrochemical Research Corporation, 7960 S. Kolb Road, Tucson, AZ 85706; (602) 574-1980
Dr. R. O. Loutfy, Principal Investigator
Dr. J. C. Withers, Business Official
DOE Grant No. DE-FG02-93ER81481
Amount: $75,000

The combustion of coal introduces hazardous emission products, including respirable particles that are ≤10 μm in diameter. The removal of these particles from the combustion gas stream is difficult due to the high temperatures and corrosive environment. A ceramic filter has the greatest potential to survive the harsh gas environment; however, ceramic filter materials which have thus far been tested are limited primarily by corrosion and inferior thermal properties. Monolithic silicon carbide (SiC) in particular has demonstrated significant potential but is susceptible to thermal shock and subsequent failure. Innovative hollow SiC fibers have been developed which can be utilized as filter elements. Control of the inside diameter to micron sizes is possible so that coal particles of ultrafine sizes can be easily separated. The fibers have very high strength (≥4 gigapascals) which suggests that they will be mechanically stable in the combustion gas stream environment. Filters will be fabricated from these hollow SiC fiber elements in Phase I, and subsequently tested at the Coal Fired Flow Facility (CFFF) at the University of Tennessee Space Institute (UTSI).

Anticipated Results / Potential Commercial Applications as described by the awardee: The development of SiC filters composed of hollow SiC fibers could result in a material that can remove ultrafine particulates from the combustion gas stream while remaining structurally stable. The high strength, high modulus fibers themselves have the potential to replace current ceramic fibers in ultralight weight applications such as advanced aircraft engines and general transportation.

11

Measurement of Mercury and Other Trace Metals in Combustion Gases--Physical Sciences, Inc.; 20 New England Business Center, Andover, MA 01810; (508) 689-0003
Dr. Lawrence G. Piper, Principal Investigator
Mr. George E. Caledonia, Business Official
DOE Grant No. DE-FG02-93ER81528
Amount: $75,000

It is planned to investigate the application of active nitrogen energy transfer (ANET) fluorescence excitation to the detection of mercury in exhaust stack effluents from coal burning power plants. The innovation is to apply dielectric-barrier discharge technology to generate active nitrogen at atmospheric pressure. Mercury fluorescence at 253.7 nm will be excited by the active nitrogen when small samples containing mercury at ppb levels are introduced into the active nitrogen discharge. Active nitrogen excitation of atomic fluorescence tends to populate only a limited number of states so that the resultant fluorescence spectrum is simple and easy to analyze. Thus, a compact instrument of modest resolution will suffice to detect the fluorescence. In the case of mercury detection, an interference filter and phototube should be adequate. The basic technique is general and has been demonstrated to allow multispecies detection at ppb levels. The use of dielectric-barrier discharge technology to generate the active nitrogen affords the opportunity to develop a light weight instrument with low power requirements (a 12 V battery) so that a truly portable instrument can be constructed. In addition, the active nitrogen source can be mounted on the end of a probe allowing direct, real-time analysis of the flue gas toxics. This research project is directed toward first optimizing the production of active nitrogen in a dielectric-barrier discharge to achieve maximum sensitivity for mercury, and then to develop techniques to allow samples to be drawn directly from a combuster exhaust into the active nitrogen source. The second component of the program will use an entrained-flow, high temperature coal combustion facility. The goal of the Phase I project is to demonstrate the sensitivity and flexibility of this technique so that a prototype instrument for monitoring mercury in flue gases can be designed and fabricated in a Phase II program.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful development of an inexpensive, portable monitor for mercury and other heavy metal toxics will have important commercial applications to the power industry as it struggles to meet ever more stringent exhaust standards. Sensitive monitoring of mercury is also important in a number of industrial locations, military bases, toxic waste sites, and gas pipelines. Simple, on-site, real-time analysis of mercury will also be invaluable during environmental remediation activities at Super Fund sites.

12

A Photo-Fragment Fluorescence Spectrometric Method for Measurement and Speciation of Mercury Emissions--Poulos Technical Services, Inc.,
7 Waterbury Court, Allentown, NJ 08501;
(609) 259-0501
Dr. Arthur T. Poulos, Principal Investigator
Mrs. Danette N. Poulos, Business Official
DOE Grant No. DE-FG05-93ER81539
Amount: $75,000

Coal sources contain significant quantities of mercury which will appear in the vapor phase during advanced coal utilization and conversion processes. This can lead to serious degradation or devaluation of processes and products, for example, in the poisoning of fuel cell electrodes and contamination of coal-derived products. New diagnostic instrumentation is needed for measurement of mercury and its compounds in coal gas streams. This will provide feedback to clean-up technologies as well as tracking of environmental emissions. This project offers a novel concept for detection of vapor phase mercury which is suitable for hot coal gas streams. It is based upon fluorescence and photofragment fluorescence phenomena which are specific to mercury and its compounds. Unlike existing methods, this concept offers capability of rapid response and real-time and in-situ monitoring capability. Importantly, it will be responsive to mercury compounds (such as $HgCl_2$, $Hg(CH_3)Cl$, $Hg(CH_3)_2$, and others) as well as elemental mercury. Because it is a spectroscopic technique, it will be effective for non-intrusive measurement in streams at high temperature and pressure. Phase I will test the feasibility of this concept through bench-scale studies on two representative mercury species. Issues to be addressed include speciation, sensitivity, linearity, and interferences.

Anticipated Results / Potential Commercial Applications as described by the awardee: This diagnostic concept should ultimately lead to an instrument for real-time, in-situ monitoring of gas phase mercury levels Commercial application will be in clean-up systems for coal gas streams and incinerators, and in environmental monitoring.

13

Control of Mercury and Other Volatile Trace Metals in Fossil and Fuel-Fired Power Generation--PSI Technology Company, 20 New England Business Center, Andover, MA 01810;
(508) 689-0003
Dr. Srivats Srinivasachar, Principal Investigator
Dr. Anthony A. Pirri, Business Official
DOE Grant No. DE-FG02-93ER81529
Amount: $75,000

Fossil-fuel fired power plants are one of the largest emitters of mercury into the environment. The primary concern with currently available mercury control technology is the relative ineffectiveness of activated carbon as a sorbent for elemental mercury. Another concern is the release of mercury into the environment, after the mixture of the ash and the contaminated sorbent is landfilled. In this project the focus is on the development of a process to remove mercury from the flue gases and isolate it. The use of cost-effective regenerable sorbents to accomplish the above objective will be examined. Phase I will consist of an experimental study to evaluate the performance of these sorbents in capturing mercury vapor species for short and long sorbent-flue gas contact time. It will also determine sorbent regeneration conditions and evaluate the effectiveness of the regenerated sorbent. In Phase II, pilot-scale testing will be performed using the best sorbents identified in Phase I. These tests will provide representative data for the actual configuration that may be used in a full-scale application.

Anticipated Results / Potential Commercial Applications as described by the awardee: A major result of this work would be a cost-effective method to control mercury and other volatile trace metal emissions in stack gases. This approach will be applicable to power plants, incinerators, smelters, and other industrial processes. Another major benefit would be the sequestration of these toxic metals in a concentrated and reusable form, rather than their disposal in a landfill or ash pond.

14

Catalytic Production of Elemental Sulfur from Sulfur Dioxide-Containing Gas Streams--Sorbent Technologies Corporation, 1935 East Aurora Road, Twinsburg, OH 44087; (216) 425-2354
Mr. Sidney G. Nelson, Principal Investigator
Mr. Sidney G. Nelson, Business Official
DOE Grant No. DE-FG02-93ER81548
Amount: $75,000

The objective of this project is to develop and demonstrate a low-cost alternative to a modified Claus plant for conversion of sulfur dioxide (SO_2) to elemental sulfur, based on the use of a new catalyst. Recently, a new, inexpensive catalyst was observed to result in the conversion of more than 50 percent of an SO_2-rich gas stream to yellow, elemental sulfur during a single pass of the gas through the catalyst bed at about 700°C and atmospheric pressure. The planned work will seek to optimize the process to achieve a substantially higher conversion efficiency. The Phase I research will consist of three tasks: a parametric study examining the effects of changes in temperature, pressure, and incoming gas composition on elemental sulfur yields; an examination of cycling of the gas through two or more beds to achieve higher conversion yields; and an examination of the expected life of the catalyst and the possible regenerability of the catalyst.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned project is expected to define the parameters under which a new catalytic process can be used to convert SO_2 in SO_2-rich gas streams to a marketable, stable, and environmentally-acceptable sulfur form. Success of the project could have a major impact on the development and future use of regenerable flue-gas desulfurization and coal gasification processes.

15

A Method and Apparatus to Monitor Air Toxics--VirTek, 618 Burroughs Road, Boxboro, MA 01719; (508) 635-9905
Dr. Val K. Bykovsky, Principal Investigator
Mr. Leon Altschul, Business Official
DOE Grant No. DE-FG02-93ER81534
Amount: $75,000

This project addresses the national need to develop an efficient method and instrument to monitor air toxics in gas flows. The current situation requires the detailed characterization of toxic air emissions from flue gases while the existing means lack selectivity and performance. New and high performance methods and detectors are needed for quality monitoring. A novel, high performance, on-line laser air toxics monitor is planned. A unique Zeeman refractive index (RI) detector will be a basis for the project. It is ultra-sensitive, robust, and high speed. However, it does measure the changes in the RI of the mixture rather than individual concentrations of the components. An innovative method of detection of the individual components with the detector is planned. The method is based on the high-speed multiple measurements over the mixture with systematic change of its parameters. To affect the mixture, an external laser will be used which can selectively heat a component by radiation with the wavelength typical for the absorption band of this component. The data obtained from the multiple measurements allow the individual concentrations to be calculated. In Phase I a laboratory setup will be designed and developed to verify the proof-of-concept of air toxics monitoring using the Zeeman RI detector and the planned method. In Phase II, further testing and refinement of the method and the air toxics monitor will be completed, culminating in the test of the monitor in the simulated conditions of a plant. In Phase III, an advanced commercial air toxics monitor based on the results of Phase I and Phase II will be designed and built.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase I testing is expected to demonstrate the ability of the proposed laser monitor to detect air toxics such as hydrogen chloride and lead. The simplicity, performance, and reliability of the method make it attractive for use in various industrial settings for quality monitoring of industrial streams. The monitor can be installed in power plants to provide reliable, on-line monitoring of air toxics.

16

Glass-Ceramic Construction Tiles from Coal-Fired Boiler Flyash--Vortec Corporation, 3770 Ridge Pike, Collegeville, PA 19426; (215) 489-2255
Dr. John S. Patten, Principal Investigator
Dr. James G. Hnat, Business Official
DOE Grant No. DE-FG02-93ER81555
Amount: $74,886

It is clearly recognized by those associated with environmental restoration that coal-fired boiler flyash is a significant contributor to the increasing shortage of landfill availability. In general, the landfill requirements for solid waste products are becoming a major environmental and economic issue. This project addresses a means of mitigating a part of the problem associated with the disposal of coal-fired boiler flyash by developing one of several likely markets for recycling this waste into glass-ceramic construction tiles. The technology planned for production of the vitrified product from the flyash is based on an advanced in-flight suspension glass melting technology currently being developed. Phase I will experimentally investigate the feasibility of using vitrified coal-fired boiler flyash as construction tiles. The Phase I effort is directed toward defining the feedstock and product glass composition/property criteria, developing test samples of the tiles being investigated, conducting evaluation tests on the tiles, and reformulating and evaluating the glass batch/flyash composition if necessary.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result of this project is the development of a commercial plant to manufacture construction tiles that use coal-fired boiler flyash as a feedstock. Nationally, the net benefits include a positive environmental impact in at least three important ways. First, the current disposal of 75 million tons of boiler flyash generated annually will be decreased. Second, displacing other naturally-occurring feedstocks will not only conserve them, it will reduce the environmental impact of mining them as well. Third, glass product reuse in manufacturing industrial products could also contribute to energy conservation efforts.

INCREASED COAL UTILIZATION, ADVANCED COMBUSTION, AND CO_2 REDUCTION TECHNIQUES

17

A Low Nitrogen Oxide Burner for Coal Combustion--BlazeTech Corporation, 145 Highland Avenue, Winchester, MA 01890; (617) 721-0085
Dr. N. Albert Moussa, Principal Investigator
Dr. N. Albert Moussa, Business Official
DOE Grant No. DE-FG02-93ER81525
Amount: $75,000

This project will investigate an innovative, proprietary burner design for nitric oxides (NO_x) from the combustion of fossil fuels. The proposed burner incorporates, for the first time, two well-known methods of NO_x reduction in a single design. In Phase I, a scale model of this burner will be constructed for pulverized coal, and tested in an existing 3 million Btu/hr combustion facility. Flue gas species (carbon dioxide, carbon monoxide, sulfur dioxide, oxygen, total hydrocarbons, and NO_x) will be measured and observations will be made for critical parameters of the burner design (flame length, shape, intensity, and stability). The technical merits and limitations of this innovative burner will be determined.

Anticipated Results/Potential Commercial Applications as described by the awardee: If successful, this burner will reduce NO_x emissions from pulverized coal combustion, and can be modified to reduce NO_x from oil and gas combustion. It can also be used in switching from oil to coal (or oil to gas) without derating. Applications include fossil fuel combustion in boilers and furnaces for power generation, steam raising, and industrial heating processes.

18

Control of Dioxin Emissions from Waste Fuel Combustion by Cofiring with Coal--Coal Tech Corporation, P.O. Box 154, Merion Station, PA 19066; (215) 667-0442
Dr. B. Zauderer, Principal Investigator
Dr. B. Zauderer, Business Official
DOE Grant No. DE-FG05-93ER81554
Amount: $75,000

Experimental evidence indicates that sulfur in coal suppresses dioxin formation from chlorine compounds during coal combustion. Therefore, cofiring coal with high chlorine, municipal refuse derived fuels (RDF) or paper industry wastes should be effective in suppressing dioxin formation from these fuels. Since sulfur dioxide (SO_2) emissions must also be controlled it is desirable to combine dioxin and SO_2 control in the combustion process. Tests in a commercial scale slagging coal combustor have shown substantial dioxin reduction when firing coal, and when cofiring coal and RDF. Separately, high SO_2 reductions were measured with sorbent injection in this same combustor. The objective of this planned Phase I experimental project is to determine the feasibility of combining the dioxin and SO_2 control in one step with sorbent injection into the slagging combustor. A chlorine compound will be used as a surrogate for the chlorine waste fuels. It will be mixed with coal and injected with the sulfur sorbent into the combustor. A set of combustion tests will be performed in which the concentration of chlorine and sorbent, injected with the coal, will be varied. For each condition, the dioxin concentration will be measured in the stack of the boiler to which the combustor is attached, using EPA approved methods. The Phase I test objective will be to achieve the same dioxin reduction in the high chlorine cases as with coal only, and at the same time achieve high SO_2 reductions. If the Phase I tests are successful, the Phase II effort will focus on fully characterizing the simultaneous dioxin and SO_2 control in the combustor using both surrogates and chlorine content waste streams.

Anticipated Results / Potential Commercial Applications as described by the awardee: The air cooled slagging combustor, whose installed cost on existing boilers is projected at less than $10/lb of steam, can efficiently cofire coal and solid waste fuel combustion with internal environmental control. The municipal refuse incineration and paper manufacturing industries are the primary markets for this combustor technology application. Successful elimination of dioxin emissions will allow both industries to continue using current chlorine based processes and avoid costly changes to other processes. It will enable them to dispose of chlorine containing sludges by cofiring them with coal in the combustor. During Phase I and Phase II of this project efforts will be implemented to market this combustor technology to these industries.

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A T-Layer Magnetohydrodynamic Alternating Current Generator--ERC, Inc., P.O. Box 417, 205 Research Park Drive, Tullahoma, TN 37388; (615) 455-9915
Dr. Y. C. L. Susan, Principal Investigator
Mr. Richard Lin, Business Official
DOE Grant No. DE-FG05-93ER81557
Amount: $74,976

It is planned to research and develop a T-Layer magnetohydrodynamic (MHD) alternating current (AC) generator. The T-Layer MHD concept is an innovative idea for practical application to MHD power. The viability of the T-Layer MHD power process has been demonstrated in the laboratory. T-Layer MHD is a process wherein a high temperature plasma layer, a T-Layer, is produced in the flow stream of an MHD device using external excitation, e.g., electric discharge. The T-Layer formed by the high energy excitation is a fully ionized plasma with extremely high electrical conductivity. In the T-Layer MHD generator, the T-Layer passes through the generator producing useful external electric power according to standard MHD power principles. The generator has advantages over the combustion driven MHD generator that make it an attractive alternative power system. For example, it has continuous electrode construction, and simple power consolidation and isolation needs; in addition, it can operate with a low temperature bulk fluid without ionization seed. The T-Layer MHD generator can produce an AC electrical output signal. It has high power density and can be made compact and lightweight. Phase I will determine the feasibility of a T-Layer MHD AC generator as a commercial product. It will analyze the physics of this device and arrive at a conceptual design for a power system. It will also determine the best near term application and market for the AC generator as a commercial product. Phase I will define an experimental apparatus and laboratory for Phase II in which proof-of-principle tests can be conducted.

Anticipated Results / Potential Commercial Applications as described by the awardee: The T-Layer MHD AC generator will provide a compact, lightweight power supply capable of high power production and an AC electric output. The generator has potential for application in MHD and related technologies. It has application to gas cooled nuclear reactor and fusion research as a large scale power system and has special applications where a simple, lightweight, small size system is sought, e.g., an airborne power supply. The T-Layer MHD principle can also be used in MHD accelerator applications, e.g., propulsion.

20

Remote Sensing Diagnostics for Magnetohydrodynamic Environments--ERC, Inc., P.O. Box 417, 205 Research Park, Tullahoma, TN 37388; (615) 455-9915
Dr. Y. C. L. Susan Wu, Principal Investigator
Mr. Richard Lin, Business Official
DOE Grant No. DE-FG05-93ER81556
Amount: $74,955

Research on remote sensing diagnostics with capabilities designed for the unique magnetohydrodynamic (MHD) environment is planned. The large differential and common mode voltages found on MHD flow trains require isolation from operating and control systems for hardware and personnel protection. Furthermore, the problems of magnetic field interference near and limited access to an MHD generator pose problems for conventional instrumentation used in the utility industry. The remote sensing diagnostics developed in this research project would provide greater and more reliable electrical isolation than is available with current power plant technology such as transformer based isolation amplifiers. Phase I research will design and construct a remote sensing voltage probe. This probe will undergo extensive bench top testing to characterize its basic capabilities and sensitivity to fringe strength magnetic fields. The bench scale testing will be followed by in-situ testing on an operational MHD flow train in which a single measurement, combustor voltage to ground, will be used to gauge the performance of the remote voltage probe in an MHD environment. DC and AC probe performance will be determined from data gathered during steady state and transient operation of the flow train. In Phase II an array of isolated remote sensing diagnostics including current, temperature, and pressure will be developed along with manufacturing technology necessary to allow commercialization of the sensors.

Anticipated Results/Potential Commercial Applications as described by the awardee: The research should provide small, highly reliable electrically isolated remote sensors of industrial ruggedness. These types of sensors are essential for the MHD power plant. As a commercial product, the sensors have application in the near future to MHD research and demonstration plants and eventually to commercial MHD. They are also applicable to other systems needing high voltage isolation of measurement diagnostics.

21

A Testing Process to Define Electrode Current Wear Mechanisms and Develop Improved Electrodes--Montec Associates, Inc., P.O. Box 4182, Butte, MT 59702; (406) 494-2596
Mr. Lawrence C. Farrar, Principal Investigator
Mrs. Cynthia K. Farrar, Business Official
DOE Grant No. DE-FG03-93ER81535
Amount: $75,000

Coal-fired magnetohydrodynamic (MHD) technology has advanced to the stage of testing large scale components to demonstrate the feasibility of the overall process for application as a viable commercial power generation technique. However, testing to evaluate the fundamental aspects of electrode wear is not being conducted. It appears that some additional understanding of gas-side component wear, specifically anode wear due to arc current levels, is essential to advance designs of anodes that can withstand high current arcs. Experimental data have shown, and theoretical calculations predict, that arc current values will increase for commercial scale channels. However, there is no experimental facility to systematically determine the effect of arc current on state-of-the-art anode wear rates and damage thresholds, even though this process is essential for improvement of MHD electrode lifetimes. The primary Phase I objective is to show that a carefully controlled bench scale technique is suitable to establish anode arc current damage thresholds for state-of-the-art anode designs and materials. The approach will use a low-cost, but technically-sound, screening-type experiment to determine damage thresholds and establish a fundamental understanding of arc current wear processes in MHD channel environments. Emphasis will be placed on using the test scheme to replicate anode wear and damage features observed in MHD channels and, via systematic metallurgical analysis, develop a fundamental understanding of the wear processes. These procedures will provide current limitation criteria for anode materials and designs. Secondary objectives include the use of this process to test alternative, state-of-the-art materials fabrication processes developed in the electrical contact industry that may have higher threshold arc current than the existing MHD channel electrode designs.

Anticipated Results / Potential Commercial Applications as described by the awardee: A development process to test new MHD channel gas-side materials should result from this project. It will provide a means to integrate state-of-the-art electrode design concepts and fabrication processes that have been established in the electrical contact industry into the development of MHD channel electrodes. The process provides a cost effective means to develop novel and advanced electrode and gas-side materials concepts. The test and evaluation techniques will be suitable for developing electrodes used in other areas such as plasma torches for waste incineration. The materials and design developed will be suitable for use in a commercial MHD power plant.

22

An Environmentally Sound Process for Utilizing Waste Tire-Derived Fuel and Railroad-Tie-Derived Fuel in Coal-Fired Stoker Boilers--
Reaction Engineering International, 77 West 200 South
Suite 416, Salt Lake City, UT 84101; (801) 328-6925
Dr. N. Stanley Harding, Principal Investigator
Dr. Michael P. Heap, Business Official
DOE Grant No. DE-FG03-93ER81559
Amount: $74,872

The United States has a large backlog of waste tires and railroad ties, growing at a rate of approximately 240 million tires/year and 14 million railroad ties/year. These waste fuels represent a sizable resource. Currently over 80% are landfilled, constituting loss of a significant resource and creating a major environmental problem. The objectives of this project are to identify barriers to the successful blending of coal with waste tires and railroad ties in stoker-fired boilers, and identify process parameters that will enable coal/tire-derived fuel (TDF) and coal/railroad-tie-derived fuel (RTDF) combinations to produce total emissions within environmental regulations. In Phase I, series of experiments will be carried out in a pilot-scale stoker to establish maximum waste tire and railroad tie replacement rate as a function of chip size; optimum feed location, overfire/underfire air ratio; optimum gas/TDF co-firing ratio (if necessary); effect of TDF and RTDF on criteria for pollutant emissions, trace hydrocarbons, particulate matter, and metals; and impact of tire belts on grate due to interaction with coal ash. This project will define the potential for coal/TDF and coal/RTDF co-firing based on technical performance and economic considerations and will establish process design parameters that will be used in the design of an optimum coal/TDF or coal/RTDF stoker system. In addition, the project will document advantages to the industrial customer that result from cofiring.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase I will provide information on combustion characteristics of co-firing TDF and RTDF with coal in stoker boilers to minimize pollutant emissions, determine optimum replacement rate as a function of TDF/RTDF properties, and maximize efficiency and minimize operational impacts.

23

Development of a Rotary Combustor for Refiring Pulverized Coal Boilers--Spinheat Limited, 1222 Bronson Road, Fairfield CT, 06430 (203) 254-0340
Mr. Michael J. Virr, Principal Investigator
Mr. Michael J. Virr, Business Official
DOE Grant No. DE-FG05-93ER81515
Amount: $75,000

The rotary combustor (RC)is being developed to refire conventional pulverized coal burners in order to reduce sulfur oxides (SO_x) and nitrogen oxides (NO_x) in utility boilers by means of combustion modification. The burner comprises a slowly revolving, perforated drum. Granular coal and limestone are introduced into the revolving drum, where they are fluidized against the artificial gravity caused by centrifugal (centripetal) force; the coal gasifies, and sulfur combines with the limestone in the normal way. The resultant coal gas is then passed through a $DeNO_x$ tube, where the fuel nitrogen is fixed, before being introduced into the original combustion chamber with final (tertiary) air and burned in a conventional flame. The RC is installed on the burner wall of a conventional coal boiler to replace the existing burners and milling equipment, thus eliminating the power consumption of the mills and raising efficiency. Limestone is fed in with the coal to capture the sulfur within the RC which is very effective as the temperature range of the rotating fluidbed is controlled. Thus, sulfur capture in excess of 90% is predicted. The RC incorporates a cooled firetube with secondary and tertiary air admission, thereby reducing NO_x to significantly lower levels than conventional burners. The Phase I objective is to demonstrate the feasibility of using the RC by establishing the design details and costs, demonstrating mechanical details on a cold model, and developing the design to a practical stage. The design of a unit to test-fire on a 500 lbs/hr(coal) combustion rig would be completed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful completion of the Phase I development of the RC would prove the viability of demonstrating the burner on a reasonably sized boiler test facility with good instrumentation. The successful development of the RC would offer utilities the opportunity of refiring their existing coal-fired steam boilers with burners which would comply with the 1990 Clean Air Act, while realizing a power gain. Both capital and running costs of the RC will be substantially less than current flue gas desulfurization and NO_x control, probably being under $100/Kw.

COAL BENEFICIATION AND TRANSPORT

24

Reconstitution of Beneficiated Coal Using the Biobinder Process--Altex Technologies Corporation, 650 Nuttman Road, #114, Santa Clara, CA 95054; (408) 982-2303
Dr. John T. Kelly, Principal Investigator
Dr. Mehdi Namazian, Business Official
DOE Grant No. DE-FG03-93ER81485
Amount: $73,533

For optimal beneficiation, coal must be finely ground to release the pyritic sulfur and ash inclusions. The resulting clean product is difficult to handle, transport and store. By reconstituting the product through pelletization, these difficulties can be overcome. However, excessive pelletization costs, and, in particular, binder costs, have limited this practice. A process has been identified for the reconstitution of cleaned coal fines. This process uses a minimal cost binder and special processing conditions to create durable fuel pellets at low cost. In Phase I the special binder and processing equipment will be used to create and test fuel pellets. The durability, weatherability, grindability, and combustion characteristics of the pellets will be determined during the project. Also, preliminary economic analyses will be combined with the best data to determine the overall feasibility of the process for reconstituting cleaned coal fines.

Anticipated Results/Potential Commercial Applications as described by the awardee: At the conclusion of Phases I and II, equipment will be available to produce limited quantities of pellets. These will be used to demonstrate good combustion characteristics in field units. The low cost pellets should find considerable application in industrial, commercial, and even residential sector combustion equipment.

25

A High-Quality Coal Water Slurry Production Process--Clarke Rajchel Engineering, P. O. Box 5128, Arvada, CO 80005; (303) 456-9266
Mr. Marcus Rajchel, Principal Investigator
Ms. Victoria A. Clarke, Business Official
DOE Grant No. DE-FG03-93ER81503
Amount: $59,848

Over the years, there have been a number of advanced coal combustion technologies which have attempted to utilize coal-water slurry (CWS) as fuel. Typically, the goals for development of CWS fuel technologies have been aimed at utilization of recovered fine coal, replacement of natural gas or petroleum, or elimination of the handling and dewatering problems associated with highly beneficiated fine coal. A drawback to the utilization of CWS as a fuel, for many of the programs, has been the lack of a source of reliable, high-quality coal-water fuel. The manufacture of consistent, stable coal-water slurries is problematic owing to the naturally broad range of coal properties and the complexity of the behavior of solid-liquid mixtures. If the CWS producer knows the effect of changing process conditions on the slurry product, adjustments in plant operating conditions can be made and the product quality can be maintained. In this Phase I project, inventive processing technology will be developed and coupled with sound engineering experimentation to achieve near perfect control over coal slurry product quality parameters. In Phase II, the fully automated CWS production process will be demonstrated at a one-ton per hour CWS production facility. When completed, the plant will be capable of producing consistent and reliable CWS from any feedstock.

Anticipated Results/Potential Commercial Applications as described by the awardee: In Phase I, the new CWS production process will control the key parameters required to optimize CWS loading, rheology, and stability. In Phase II, a ton-per-hour CWS plant test program will be executed. A major goal of this project will be the demonstration of CWS burner retrofit technology for oil fired boilers. The process technology and information gained from this project will have an immediate impact on the coal slurry combustion technology demonstration project.

ADVANCED TECHNOLOGY FOR THE RECOVERY, STORAGE, AND UTILIZATION OF NATURAL GAS

26

Development of an Exploration Strategy Designed for Identifying Regions Capable of High Gas Utilizing the Open-Hole Cavitation Technique--Advanced Resources International, Inc., 165 South Union Boulevard, Suite 816, Lakewood, CO 80228; (303) 986-2121
Mr. A. David Decker, Principal Investigator
Mr. Donald E. Wicks, Business Official
DOE Grant No. DE-FG03-93ER81502
Amount: $74,692

The remarkable success achieved for producing gas from coal seams in the San Juan Basin can be attributed largely to utilization of the innovative open-hole cavitation (OHC) technique. Nearly 70% of the San Juan Basin coalbed methane is produced from OHC wells even though they only account for 20% of the producing coalbed methane wells. Most OHC wells are located within a northwest trending fairway situated in the north central portion of the San Juan Basin. Within this fairway, wells completed with the OHC outperform hydraulic fractured wells by a factor of five. Outside the fairway, hydraulically fractured wells typically outperform OHC wells.

The production variability is related to regional changes in reservoir conditions as reflected by varying geologic characteristics. The geological parameters leading to successful OHC wells have been inadequately studied for predictability using the OHC technique outside of the existing cavity fairway. The planned research is directed towards resolving the geologic systems favorable to achieving cavitation with initial high gas rates. Preliminary production mapping suggests the cavitation fairway is characterized by a northwest trend extensional fractured zone which has intersected coal reservoirs at full adsorptive capacity with free gas in the fractures. Phase I will delineate the origin of this unique system by (1) establishing basement wrench faulting tectonics using seismic and stratigraphic mapping, (2) thermal modeling to help quantify origin of high gas retention and trapping mechanisms, and (3) extensional, low stress setting, and fracturing hypothesis to be supported with surface fracture mapping using remote imagery. In Phase II the predictive model calibrated against the production anomaly fairway in the San Juan Basin will be used in screening other coal basins for regions suitable for the OHC completion technique.

Anticipated Results / Potential Commercial Applications as described by the awardee: A predictive exploration rationale and model for locating potential coalbed methane production using cavity completion methods will be developed. The predictive model will be calibrated against the cavity fairway in the San Juan Basin. In Phase II, the model and methodology will be applied to other coal bearing basins in an effort to locate regions where the OHC technique could be utilized. Successful identification of new cavity fairways would result in the discovery of substantial new gas reserves.

27

A Novel Process for the Removal of Nitrogen from Nitrogen-Containing Natural Gas: Development of Water-Based Absorbents--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. David K. Lyon, Principal Investigator
Dr. Rod Ray, Business Official
DOE Grant No. DE-FG03-93ER81551
Amount: $74,919

Domestic natural gas provides an increasingly important portion of the U.S. energy supply. Estimated U.S. gas reserves are about 1000 trillion standard cubic feet (SCF) -- or about 1000 quads. Fully 25% of the estimated U.S. natural gas reserves are contaminated with nitrogen (N_2) to the extent that the gas cannot be used without processing to reduce the N_2 concentration. No technology exists today for the cost-effective removal of N_2 from natural gas at the wellhead. A process is under development for purifying N_2-contaminated natural gas at the wellhead. In Phase I, the N_2 will be separated from the rest of the natural gas using a regenerable absorbent. The N_2 absorbents are based on solutions of transition-metal complexes. These absorbents ideally will have the following characteristics: (1) rapid absorption of nitrogen at the pressure and temperature of the natural gas feed stream (high pressure and ambient temperature), (2) rapid desorption of nitrogen under mild conditions (ambient pressure and moderate temperature), (3) extremely high selectivity for nitrogen over methane (and the other natural gas components), and (4) other properties that combine to yield an economical process. The understanding of the relationship between the molecular structure of N_2-binding compounds and their properties will be used to increase the selectivity of the N_2 absorbent--the key shortcoming of current absorbents. Increasing selectivity while retaining the properties of low cost and long lifetime will lead to processing costs for removal of N_2 from natural gas of less than $0.25/1000 SCF, the cost target for this process. High selectivity will also keep gas losses for treatment below a 3% limit imposed by environmental and economic constraints.

Anticipated Results / Potential Commercial Applications as described by the awardee: An economic process for purifying N_2-contaminated natural gas would render up to 250 trillion SCF (250 quads) of low-grade natural gas saleable. This gas, at today's prices, is valued at $7 to $8 billion each year over a 50-year period. In addition, this project will serve as the groundwork for development of other liquid-absorbent-based separation processes such as the separation of olefins from paraffins and fractionation of olefin isomers.

28

Natural Gas Conversion to Ethylene in Intermediate Temperature Fuel Cells--Eltron Research, Inc., 2830 Wilderness Place, Suite E, Boulder, CO 80301-5455; (303) 440-8008
Dr. Michael Schwartz, Principal Investigator
Ms. Eileen Sammells, Business Official
DOE Grant No. DE-FG02-93ER81506
Amount: $74,988

This planned program will be directed towards developing the scientific and technical insight necessary for evaluating an intermediate temperature fuel cell for promoting the highly selective conversion of natural gas to ethylene in its anode compartment. This will be achieved in fuel cells incorporating advanced solid electrolyte and anode electrocatalyst. The significance of this anode electrocatalysis strategy is the expectation that immobile surface lattice O^{2-} species will be available for electrochemical oxidation to O^-. These latter species will be sites responsible for promoting initial methane activation by transient formation of OH^-. Proton conduction will then proceed across the solid electrolyte via intermediate OH^- sites to the oxygen reduction side, continuously regenerating immobile lattice O^- species at the methane oxidation surface. The important anticipated feature of this technology will be high selectivity towards promoting the desired methane oxidative dimerization reaction while avoiding susceptibility towards formation of deep methane oxidation products.

Anticipated Results / Potential Commercial Applications as described by the awardee: Intermediate temperature fuel cells for exclusive natural gas conversion to ethylene, if successful, could lead to substantial benefits. Since ethylene is a widely used chemical industry feedstock material, this technology would be of significant economic and technical benefit to the nation by both lowering the cost of an important feedstock chemical.

29

Biological Production of Sulfur from Hydrogen Sulfide--Engineering Resources, Inc., P.O. Box 3682, Fayetteville, AR 72702; (501) 575-4108
Dr. Edgar C. Clausen, Principal Investigator
Mr. Stephen S. Adams, Business Official
DOE Grant No. DE-FG05-93ER81484
Amount: $75,000

About 100 trillion cubic feet of proven and future natural gas reserves are expected to have high hydrogen sulfide (H_2S) concentrations, requiring treatment and removal. Current treatment processes are expensive, emit large quantities of sulfur gases to the environment, and can be applied only to very large reserves. Technology that can be economically applied to small, as well as large, gas reserves is needed to ensure cheap and abundant natural gas in the future. This project will investigate a simple biological process for the conversion of H_2S into elemental sulfur. Certain anaerobic photosynthetic bacteria metabolize H_2S and carbon dioxide (CO_2) to produce sulfur and cell mass. Prior research has concentrated on the use of Chlorobium species, which deposit sulfur outside the cell membrane where it is easily recovered by density difference. The microorganisms can use gas with a wide range of H_2S concentrations, and other gases, such as nitrogen, have no effect upon the reaction. CO_2 is used in the reaction, reducing the emission of greenhouse gases. A single cell protein by-product is also produced which has a large market as an animal feed. The purpose of this three-phase study is to demonstrate the concept and perform bench-scale experiments to define scale-up parameters for commercial design. In Phase I, bacteria for producing extracellular sulfur from H_2S will be screened, and the best selected for optimization of sulfur yield and rates. Reactor studies will be performed to define reaction rates and retention times for design and economic projections. Phase II of the project will investigate advanced bioreactor concepts to minimize reactor volume. Methods for sulfur and single cell protein recovery will be developed. A bench-scale unit utilizing the best bacteria and bioreactor system will be operated for a prolonged period to confirm the viability of the culture. Scale-up parameters will be defined and a large commercial design and economic analysis conducted. Phase III will involve a field demonstration of this process.

Anticipated Results / Potential Commercial Applications as described by the awardee: The development of this technology will result in a simple economical process for sulfur production, involving only a bioreactor and product separator. Gases passed through the bioreactor would have the H_2S removed, with effluent gases introduced into the pipeline. This simple process should find wide application in natural gas processing.

30

Biological Removal of Coal Mine Methane--Engineering Resources, Inc., P.O. Box 3682, Fayetteville, AR 72702; (501) 575-4108
Dr. E. C. Clausen, Principal Investigator
Mr. Stephen S. Adams, Business Official
DOE Grant No. DE-FG05-93ER81483
Amount: $75,000

Atmospheric concentrations of methane are currently increasing at a rate of one percent annually. Emissions of this greenhouse gas from coal mines now amount to about 65 million tons annually, and are increasing steadily. Methane adsorbed onto internal coal surfaces is released as the coal is mined. This gas is vented to the atmosphere from gob wells or with ventilation air. The methane concentrations are dilute, and recovery is rarely economical. This project involves a novel concept to convert waste methane into a high value product, single cell protein (SCP) for animal feed. Methanotrophic bacteria convert methane into cell mass with a high protein content that has been shown to be a suitable supplement for protein in animal and poultry diets. The fermentation is aerobic, requiring at least an equal volume of oxygen with methane; consequently, dilute methane concentrations are required. Phase I will screen the various methanotrophs to select those that have the fastest growth rates and highest yields of SCP. Continuous culture studies will be conducted with the best bacteria to define reaction kinetics and minimal reactor volume. The design and economics of a process to produce SCP from coal mine methane will be projected to determine feasibility. Phase II will define engineering and marketing parameters for large scale production of SCP. A prototype unit will be constructed and operated in phase III to demonstrate scale-up.

Anticipated Results / Potential Commercial Applications as described by the awardee: There are 180 underground coal mines that discharge large quantities of methane into the atmosphere. The average discharge from the ten largest methane emitting mines is 11 million cubic feet per day. Conversion of the gas from one of these mines into SCP would generate $30 million annually, requiring nominal capital and operating cost. Therefore, significant economic and environmental incentives exist for commercialization of the technology.

31

A Pressure Swing Adsorption/Temperature Swing Adsorption Process for Nitrogen Rejection from Natural Gas--Northwest Fuel Development, Inc., 4064 Orchard Drive, Lake Oswego, OR 97035; (503) 699-9836
Dr. Peet M. Soot, Principal Investigator
Dr. Peet M. Soot, Business Official
DOE Contract No. DE-FG03-93ER81552
Amount: $75,000

A combination pressure swing adsorption (PSA)/temperature swing adsorption (TSA) process will be developed for removing nitrogen from low-quality natural gas in order to produce pipeline quality natural gas on a small scale. Nitrogen rejection remains the major technoeconomic hurdle for utilizing major resources of low-quality natural gas. This will provide a methodology for producing a valuable fuel resource out of gas resources which are currently either being thrown away or are left unused in the geologic formations in which they were discovered. This project will develop a potentially patentable process for nitrogen rejection applied on a small scale, allowing the matching of processing capabilities to the scale of low-quality gas production. The Phase I project will include laboratory testing of PSA parameters for different adsorbents, review and selection of possible sites, and will define the variables and optimize the PSA process. A team has been established which will develop the applicable technologies. The team will have access to numerous sites where low-quality gas resources are available.

Anticipated Results / Potential Commercial Applications as described by the awardee: Nominally, 25% of the Nation's gas reserves are low quality. This is a resource of about 250 trillion cubic feet (TCF) of natural gas. The successful development of a nitrogen rejection process provides economic, environmental, and national security benefits. Initial economic assessments show the price competitiveness of the process. Environmental benefits arise from the potential capture of methane emissions (a greenhouse gas). The low-quality gas resources base is domestic, providing the Nation with an improved energy balance and security.

32

Development of Long Wavelength Infrared Detectors for Trace Gas Detection--Structured Materials Industries, Inc., Enterprise Development Center, 240 Martin Luther King Boulevard, Newark, NJ 07102; (201) 471-3589
Dr. Gang Sun, Principal Investigator
Ms. D. Rechyleben, Business Official
DOE Grant No. DE-FG05-93ER81540
Amount: $74,971

Long wavelength infrared (IR) detectors will be produced for application in trace gas analysis. The detector is formed by an InAs/$In_xGa_{1-x}Sb$ strained layer superlattice (SLS). It will be demonstrated in this project that InAs/$In_xGa_{1-x}Sb$ SLSs with effective band gaps over a wide range of the IR spectrum can be grown and lattice-matched to GaSb substrates (a_{GaSb} = 6.0959Å) by properly designing the alloy compositions and layer thicknesses of the SLSs. The use of lattice-matched structures will eliminate or significantly minimize the formation of misfit dislocations in the active layers which act as scattering centers and consequently degrade the electrical properties of the detectors. Hence, high structural and electrical quality will be maintained by eliminating the dominant dislocation scattering. In Phase I molecular beam epitaxy will be used to deposit InAs/$In_xGa_{1-x}Sb$ SLSs corresponding to a cutoff wavelength of about 8μ on GaSb substrates. The structural parameters and photoresponse of the grown films will be studied. Films demonstrating good structural quality and desired photoresponse will be processed into devices which, in turn, will be electrically and optically characterized. In Phase II, the design and growth of InAs/$In_xGa_{1-x}Sb$ SLSs as well as device processing will be refined based on the results obtained in Phase I, and a prototype trace gas analyzer will be demonstrated.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful development of long wavelength infrared detectors will have immediate applications in exploiting atmospheric transmission windows, remote sensing of atmospheric gases, molecular spectroscopy, and in supplying tracking information on objects in space. Development of an economical broad range trace gas analyzer capable of sensing fuels or pollutants will significantly impact environmental and energy programs.

COAL-BASED POWER SYSTEMS TECHNOLOGY

33

A Carbonate Fuel Cell Monolith for Low-Cost and High Power Density Operation--Energy Research Corporation, 3 Great Pasture Road, Danburry, CT 06813; (203) 792-1460
Mr. Randolph Bernard, Principal Investigator
Dr. Hans Maru, Business Official
DOE Grant No. DE-FG05-93ER81510
Amount: $74,976

This project is aimed at improvement in power density and lowering of the carbonate fuel cell costs. The present generation of carbonate fuel cells is quite attractive for baseload utility applications because of their high efficiency, superior environmental performance, and competitive cost of electricity. However, commercial applications of carbonate fuel cells can be significantly expanded if the power density is increased by a factor of three (from one to three kw/m^2). Such an increase would not only lower the power plant and stack replacement cost, but also improve volumetric and weight densities. While incremental improvements in stack performance have been carried out under DOE/Electric Power Research Institute and other programs, the emphasis of this project will be to achieve a quantum jump in power density with accompanying cost benefits by innovative cell design. A monolithic carbonate fuel cell design using thin electrodes is planned in Phase I for achieving very high power density operation and reduction of cell materials use. This cell design makes high power density operation feasible by providing 12% higher active area within the same geometric area, lowering mass transfer resistance of the anode as well as the cathode, and reducing cell internal resistance by about 60%.

Anticipated Results / Potential Commercial Applications as described by the awardee: A high power density carbonate fuel cell design will be developed. This design, besides offering a high efficiency, cost effective baseload power plant for utilities for clean power production, will make the carbonate system attractive for other applications such as transportation, industrial co-generation in the chemical industry, and power peaking applications in the electric utility market.

34

Advanced Ceramic Fibers for a Carbonate Fuel Cell Matrix--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 792-1460
Dr. Chao-Yi Yuh, Principal Investigator
Dr. Hans Maru, Business Official
DOE Grant No. DE-FG05-93ER81512
Amount: $74,960

The attractiveness of carbonate fuel cell power plants can be significantly enhanced by extending the life of the fuel cell stack beyond the present design life of 40,000 hours. Loss of sealing efficiency of the matrix during thermal cycling appears to impact the useful life of the carbonate fuel cell. The carbonate fuel cell life can be extended by improving the strength and thermal cycleability of the matrix. The goal of the planned research is to improve the strength and thermal cycleability of the electrolyte matrix by reinforcing it with strong ceramic fibers. A novel fiber manufacturing technology able to provide strong robust fibers for reinforcing composite materials will be used to produce strong ceramic fibers stable in the carbonate electrolyte. In this Phase I program, the matrix fabrication process will be improved to disperse the fiber uniformly. The unique fiber produced will be evaluated for its stability in molten carbonate. The fiber-reinforced matrix will be evaluated in out-of-cell thermal cycling testing. The fibers and matrix will be further optimized in Phase II in out-of-cell, single-cell, and sub-scale stack testing.

Anticipated Results / Potential Commercial Applications as described by the awardee: The ultimate objective in this research is to develop a strong ceramic fiber that can reinforce the carbonate fuel cell matrix to improve its thermal cycling strength. The developed fiber will be used in commercial stacks for long-life fuel cell power plant application. This research, if successful, could lead to a speedy commercialization of carbonate fuel cell technology. The developed strong ceramic fiber could also be very useful for reinforcing other types of advanced composite materials.

35

An Improved Carbonate Fuel Cell Design--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 792-1460
Mr. Randy Bernard, Principal Investigator
Dr. H. C. Maru, Business Official
DOE Grant No. DE-FG05-93ER81511
Amount: $74,972

Coal-based power systems can provide an effective means for meeting U.S. energy requirements. Coal-derived and other hydrocarbon fuels can power highly efficient fuel cells in a wide variety of applications. To realize this objective, advances must be made to improve the performance and reduce the cost of fuel cell systems. This project addresses cost and performance of carbonate fuel cells that can readily use coal-derived fuels. Investigation of an innovative means for achieving reduced capital costs together with a streamlined system design is planned. A major opportunity for accomplishing these objectives exists in the area of anode offgas management by simplifying the method of recycling carbon dioxide to the fuel cell cathode. In Phase I system design analysis, tradeoff analysis, and bench-scale fuel cell testing will be carried out.

Anticipated Results / Potential Commercial Applications as described by the awardee: Because of its outstanding thermal efficiency and very low pollution characteristics, the carbonate fuel cell will become a significant energy conversion technology for electric power generation by the end of this century. The planned simplification of the fuel cell system will contribute significantly toward achievement of this goal.

36

An Innovative Clean High Temperature Air Heater (HTAH) for Coal-Fired Gas Turbines--Manufacturing and Technology Conversion International, Inc., P.O. Box 21, Columbia, MD 21045; (301) 982-1292
Dr. Ravi Chandran, Principal Investigator
Mr. Joe Epstein, Business Official
DOE Grant No. DE-FG05-93ER81521
Amount: $74,982

An approach to significantly enhancing the efficiency, economy and environmental control capabilities of a combined-cycle, coal-fired power plant is to apply presently available pulse combustion technology to a system that can use state-of-the-art materials, components, and sub-systems. The system consists of a high-temperature air heater for raising gas turbine compressor air temperatures to near turbine inlet requirements followed by supplementary turbine duct firing with natural gas to match turbine inlet air requirements. Emissions of nitrogen oxides, sulfur oxides, and particulates are reduced to lower levels than can be expected from solely increasing power generation efficiency. Phase I will experimentally demonstrate the high flue-gas to compressor air heat transfer rates available from the pulse combustion technology. It will also establish a matrix data base for mass flow rates, pressure, and temperature that can be used in designing the high-temperature air heater section. In Phase II a reference integrated combined-cycle system can then be designed for feasibility systems studies of performance and economics as well as for a sensitivity analysis, off-design analysis, and transient performance (start-up, shutdown, and upset conditions).

Anticipated Results/Potential Commercial Applications as described by the awardee: DOE is presently supporting programs seeking to utilize coal more efficiently and cleanly for gas-steam turbine combined-cycle plants for the near term. The anticipated successful completion of the Phase I, II and III efforts can have a profound effect on implementing this Nation's energy policy with respect to the environment, self-sufficiency, and security all within the competitive domestic and international marketplace. The near-term benefits from a successful project could result in an early market entry for a coal-fired combined-cycle system with high efficiency and very low emissions.

ENHANCED OIL RECOVERY

37

Optimization of Recovery and Contamination Minimization for Oil Production Water--Insitec, Inc., 2110 Omega Road, Suite D, San Ramon, CA 94583; (510) 837-1330
Dr. Donald J. Holve, Principal Investigator
Dr. Donald J. Holve, Business Official
DOE Grant No. DE-FG03-93ER81488
Amount: $75,000

Hydrocyclones have been used for liquid/liquid separation and for degassing liquids for more than forty years and may ultimately be the unit of operation of choice for oil/water separation on offshore platforms and on the ocean seabed because of their compactness and simplicity of operation. However, fluid shear breakup of large oil droplets and perhaps even formation of a stable emulsion have limited the widespread use of hydrocyclones as liquid-liquid separators. New approaches to hydrocyclone design are currently being developed in conjunction with fundamental experimental and theoretical research. To achieve the levels of separation efficiency needed in practice, the efficiency of removing particles in the size range between 10 and 20 microns must be increased significantly without concomitant drop breakup. In order to quantify the efficiency of particle separation, an in-situ optical measurement technique is required to measure the input and output oil droplet concentrations of the hydrocyclone. This Phase I project will modify and optimize an optical instrument configuration which addresses the hydrocyclone diagnostics questions.

Anticipated Results / Potential Commercial Applications as described by the awardee: Measurements of hydrocyclone efficiencies for liquid-liquid separation will lead to applications to liquid hydrocarbon emissions control recovery and development of continuous low cost emission monitors.

38

A Geostatistical Analysis of Crossborehole Seismic Data for Reservoir Characterization--Justice Associates, Inc., P.O. Box 985, Addison, TX 75001-0985; (214) 404-1404
Dr. James H. Justice, Principal Investigator
Dr. James H. Justice, Business Official
DOE Grant No. DE-FG05-93ER81558
Amount: $72,660

Improved management of hydrocarbon reservoirs may be the most important key to maintaining or expanding the petroleum/natural gas production capability of the U.S. in the world market. New interwell seismic imaging technologies can provide high resolution imaging of the distribution of reservoir parameters necessary for improved reservoir description, simulation, and management. This technology offers one of the few means available today for evaluating the state of the reservoir between sparsely distributed wells. Reservoir simulation provides an important means for modeling and predicting the performance of the reservoir, particularly when expensive enhanced oil recovery (EOR) technologies are implemented. Important field development and management decisions that carry significant economic consequences for the company making them are often based on the forecasts provided by these simulators. The integration of new interwell seismic imaging technologies with other data types within a geostatistical framework for the purpose of building improved reservoir (simulation) models will be investigated in Phase I in an effort to achieve improved production forecasting and management of hydrocarbon reservoirs. A successful marriage of these technologies will find worldwide application.

Anticipated Results / Potential Commercial Applications as described by the awardee: Techniques developed here for integrating interwell seismic data with other data types in reservoir characterization will find commercial application and will help to stimulate the commercial market that is now developing for interwell seismic data acquisition and processing services. The result should be new markets for new seismic imaging technology and improved efficiency and reliability in reservoir simulation, management, and production forecasting. The worldwide petroleum market is available to this new technology through field services, consulting, and training.

39

Transporting Mobility Control Agents to High Permeability Thief Zones--K & A Energy Consultants, Inc., 6849 East 13th Street, Tulsa, OK 74112; (918) 835-9524
Dr. Dwight L. Dauben, Principal Investigator
Dr. Dwight L. Dauben, Business Official
DOE Grant No. DE-FG03-93ER81550
Amount: $ $75,000

This research project will directly address the problem of sweep improvement for enhanced oil recovery (EOR) processes. One of the major problems in conducting an efficient EOR process is the control of the injected fluids. In most field applications of miscible or immiscible solvent drives, such as carbon dioxide or light hydrocarbon floods, the presence of reservoir heterogeneities leads to early solvent breakthrough. By offering a path of least resistance, the high permeability streaks or thief zones take the bulk of the injected solvent, and, as a consequence, large volumes of the reservoir oil are left unswept. Redirecting the injected solvent so that previously unswept volumes of the reservoir can be accessed allows for additional oil recovery. This requires in-depth plugging of these high permeability streaks. The efficacy of the diverting process would be further increased if the plugging mechanism was implemented via the injected solvent, as this would deliver the plugging agents directly to the thief zone taking the solvent. This Phase I investigation addresses that issue by studying a simple scheme whereby a plugging agent soluble in the injected solvent is added at the wellhead. The plugging agent will come out of solution after the solvent has penetrated some distance into the reservoir, and thus plug the thief zone taking the bulk of the solvent.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project addresses an extremely significant technological problem associated with miscible solvent EOR processes, namely the in-depth plugging of thief zones. An additional 100 billion barrels of unrecovered oil could be accessible if the sweep efficiency of the injected EOR solvent could be improved; this study has the potential to access this oil. Because this technology applies to any EOR solvent system, it has commercial significance in a very large number of producing fields. The combination of improved efficiency and greater recovery represented by this technology could lower U.S. dependence on foreign crude supplies by as much as 10 billion barrels.

ADVANCED FOSSIL RESOURCE UTILIZATION

40

A Complete Combustion Analysis Using a Combination Fourier Transform Infrared and Raman Spectrometer–Advanced Fuel Research, Inc., P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. Stuart Farquharson, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG-05-93ER81508
Amount: $74,963

A continuous emission monitoring system based on a combination Fourier Transform Infrared and Raman spectrometer (FT-IR/FT-Raman) is planned for analysis of flue gas and combustion efficiency to enhance the development of U.S. fossil resources for energy conversion. The unique instrument design employs a single interferometer that can simultaneously acquire both infrared and Raman spectra. The complementary nature of these two spectroscopy is capable of measuring ppm levels of water; carbon, sulfur, and nitrogen oxides; ammonia; unburned hydrocarbons; and chlorinated compounds. Raman spectroscopy can measure percent levels of these compounds, as well as oxygen and nitrogen thus allowing determination of combustion efficiency. Furthermore, measurements of infrared radiation extinction can be used to determine particle size, distribution, and concentration. In addition, infrared measurements of molecular rotational fine structure can be used to determine gas phase temperature. Finally, simultaneous measurement of carbon dioxide by infrared and Raman spectroscopy can provide a continuous self-calibrating system. Phase I will involve modification of a state-of-the-art interferometer to simultaneously perform infrared and Raman measurements and demonstrate its ability to monitor appropriate components in a model combustion reactor. Phase II will develop a rugged spectrometer and explore the ability for this system to improve burner efficiency, thereby reducing environmental pollution, and to determine compliance for advanced fossil fuel combustors.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful completion of Phase I will yield a stand alone instrument capable of complete characterization of emissions from a combustor or incinerator. This will include quantitative measurements of products of combustion and environmentally harmful gases, the ability to calculate combustion efficiency, the determination of gas phase temperatures, the characterization of particulate matter, and redundant measurements providing long term reliability. The instrument could also be used for continuous emission monitoring of Government and municipal incinerators, fossil-fuel fired power plants, kilns, boilers, thermal oxidizers, chemical and petrochemical scrubbers, and dispersion and vent stacks.

41

Design and Construction of a Novel High Force Magnetic Separator--Advanced Materials Corporation, 100 North Bellefield Avenue, Bellefield Towers, Pittsburgh, PA 15213; (412) 268-5649
Dr. S. G. Sankar, Principal Investigator
Dr. S. G. Sankar, Business Official
DOE Grant No. DE-FG05-93ER81553
Amount: $74,955

The planned work is an investigation of high energy permanent magnet separator designs whose express purpose is to provide an efficient means for slurry reactor wax/catalyst separation in the Fischer-Tropsch process using an iron-based catalyst. These studies will involve magnetic circuit modeling and optimization as well as bench-type runs with slurry reactor waxes/catalyst so as to determine the efficacy of the separator design. Phase I will focus on (1) the magnetic character and particle size of the Fischer-Tropsch catalyst, (2) the proper magnet size and configuration to maximize the magnetic force density for the known magnetic character of the catalyst, (3) the effects of flow rate on the separation yield, (4) the degree of separation on a single pass, and (5) the need for multistage separation to obtain wax recovery which would meet the hydrocracking requirements of <5 ppm solids content. This study will provide a data base upon which larger scale wax separators could be constructed for applications to slurry bubble column reactors.

Anticipated Results / Potential Commercial Applications as described by the awardee: The proposed magnetic separator will provide a simple, reliable and economical means of separating magnetic impurities from liquid fuels, minerals, pharmaceuticals, and food products.

42

An Optical Methanometer for the Remote Detection of Methane Gas in Hazardous Areas--Illimite Corporation, P.O. Box 18529, Rochester, NY 14618-0529; (716) 271-7128
Mr. Nicolas Poulton, Principal Investigator
Mr. Nicolas Poulton, Business Official
DOE Grant No. DE-FG05-93ER81543
Amount: $75,000

The need for a portable remote methane detection instrument has been identified by members of Government and industry. The key feature of this device would be to identify and quantify methane gas at a significant physical distance from the gas. The availability of this type of instrument would increase coal mine productivity and improve the safety of mining operations. Because of the hazardous environment in which a remote methanometer would be used, it must not only meet the design requirements for the detection and measurement of methane but also be structurally strong and intrinsically safe. A proof of concept demonstration was developed that uses the detection of differential absorption of infrared energy as its operating principle. The proof of concept instrument was not an optimal or manufacturable design and was not suitable for evaluation, test, and the requisite additional research in an underground mine because of both electronic and mechanical design. The planned project builds on the proof of concept work and develops advanced prototype instruments suitable for Phase II research and development in a working coal mine. The Phase I work plan includes the completion of an advanced prototype design, identification and evaluation of proprietary component suppliers, procurement of requisite materials and construction of a small number of prototype instruments. In addition, the Phase I work plan details the subsequent activities required to proceed from advanced prototypes (Phase I) through evaluation, research and development, and final design stage (Phase II) prior to full commercialization (Phase III).

Anticipated Results / Potential Commercial Applications as described by the awardee: Working prototypes produced in Phase I, suitable for use in their intended environment, should provide the hands-on experience required to complete a viable remote methanometer design during Phase II. Substantial commercial potential for the device exists in the U.S. coal mining industry as well as through export of the instrument to other countries. Additional opportunity exists for follow-on instruments that would be developed in Phase III. These devices would use the same instrument structure but with internal elements designed for detection of other gases found in hazardous areas of petrochemical and gas distribution facilities.

43

Use of Supervisory Control Techniques for Optimization of Environmental Emissions in Power Plants--Praxis Engineers, Inc., 852 North Hillview Drive, Milpitas, CA 95035; (408) 945-4282
Ms. Suzanne Shea, Principal Investigator
Mr. Randhir Sehgal, Business Official
DOE Grant No. DE-FG03-93ER81495
Amount: $74,951

This project involves the development of a real-time supervisory optimization and control software package that will assist plant operators in running power plants at the lowest possible cost under changing conditions, while meeting all emissions regulations. Coal-fired power plants account for 56% of the electricity produced in the United States, resulting in emission of large quantities of particulates, sulfur dioxide, nitrogen oxides (NO_x), carbon monoxide, and carbon dioxide, as well as solid waste products such as ash and flue gas desulfurization sludge. To control all of these substances within acceptable limits while meeting power production requirements and maintaining a high efficiency in the boilers poses a severe problem in constrained optimization. These objectives must also be met in a climate of increasing competitive pressures on utilities. The objectives of this Phase I effort are to determine the feasibility of developing an on-line software package for minimizing the cost of power plant operations, to select the best technical approach to this problem, and to develop a conceptual design of the software package. In Phase I, supervisory control formulations will be developed to deal with a selected subset of key power plant control interactions including those between NO_x emissions, coal fineness, air distribution, and the costs of electricity. A number of technical approaches including analytical and stochastic modeling and nonlinear optimization, neural networks, and fuzzy control will be examined before selecting one for use in system development. A conceptual design of the software will also be developed in Phase I using the selected control approach, and the system development will be completed in Phase II. The system will be designed to be easy to customize for different plants and easy for operators to learn and use.

Anticipated Results/Potential Commercial Applications as described by the awardee: The system has a wide-ranging market potential both as an off-line tool and as an on-line optimization and control package. As environmental regulations become more stringent, all power plants using coal, gas, or oil will require systems like this for optimal operation. There will also be a need for such systems to manage central dispatch of power plants to optimize power costs while minimizing emissions. It is expected that plants using optimization will save about 1% of the fuel costs.

CLIMATE CONTROL TECHNOLOGIES FOR TRANSPORTATION SYSTEMS

44

A Waste Heat Powered Stirling Truck Refrigerator--Creare, Inc., P. O. Box 71, Hanover, NH 03755; (603) 643-3800
Mr. Martin A. Shimko, Principal Investigator
Mr. Robert A. Hickin, Business Official
DOE Grant No. DE-FG02-93ER81627
Amount: $74,942

An innovative waste heat powered duplex Stirling cooler for heavy duty truck refrigeration is planned. The machine will exploit a portion of the waste heat energy contained in the diesel engine exhaust to power the Stirling engine component of the refrigerator. A unique design provides high efficiencies, while eliminating the friction, wear, seal leakage, and contamination problems of current Stirling machines. The use of helium as the working fluid makes this machine environmentally benign and eliminates the release of chlorofluorocarbons (CFCs) to the atmosphere from conventional truck refrigerators. The thermodynamic basis and critical component reliability of this machine design have already been experimentally demonstrated in previous work. The feasibility demonstration in Phase I will therefore focus on implementing an innovative method of scaling previous cryocooler designs to this specific application, and on a proof-of-principle hardware test to examine specific application questions and verify expected performance. The preliminary design produced in Phase I will address fabrication issues, cooling and heating performance, efficiency, dimensions, and weight, and will set the stage for full-scale prototype fabrication and testing in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: In addition to providing waste heat powered refrigeration for trucks, this basic design can be adapted to any application presently employing CFCs in a vapor compression cycle, including residential, commercial, industrial and mobile refrigeration, air conditioning, and space heating. Because the refrigerator is primarily waste heat powered, it increases a truck's energy efficiency while eliminating CFC use, and will therefore create immediate commercial potential in the truck refrigerator market. Properly adapted designs could exploit solar power to provide fuel energy free residential and commercial heat pumping and air conditioning in the Southwest Sunbelt.

45

A Small High Rate Thermal Storage System for Electric Vehicles--Instatherm Company, 101-B Woodwinds Industrial Court, Cary, NC 27511; (919) 469-8783
Mr. Peter Carr, Principal Investigator
Mr. William H. Ufferman, Business Official
DOE Grant No. DE-FG05-93ER81546
Amount: $74,804

The provision of acceptable levels of occupant comfort in an electric vehicle (EV) adds considerably to the load on the battery system. Batteries barely store enough energy to provide an adequate range without any auxiliary load. The addition of major power-consuming options, such as air conditioning, will have to be carefully managed to prevent this limited range from dropping well below an acceptable threshold. A major aid in managing air conditioning loads will be achieved by coupling a small "cool" storage system with the active air conditioning (a/c) unit. This small system will (1) take care of peak loads, allowing a smaller and more efficient active a/c system, (2) handle the cooling load when peak power is being withdrawn from the battery, and (3) provide an effective means of utilizing modest levels of solar energy. Such a system will also offer the unique advantage of being able to pre-cool a hot passenger compartment prior to entry. Typical thermal storage media preclude high heat transfer rates from physically small storage systems. However, because of continuous gas evolution and condensation, a high thermal storage density clathrate-hydrate system offers the potential for the necessary heat transfer rates within the EV size and weight limitations. Phase I will quantify the maximum achievable discharge rates for several clathrate hydrate systems. Charge rate data will also be accumulated on the same systems. This heat transfer rate data, plus representative EV thermal loads and heat pump performance, will allow a preliminary system design and viability assessment.

Anticipated Results / Potential Commercial Applications as described by the awardee: The availability of a small, high storage density, high discharge rate thermal storage system will enable electric, hybrid-electric, and powered highway vehicles to offer more efficient, better performing climate control than present internal combustion (IC) engined vehicles do. The application of such a thermal storage system to IC vehicles will offer a similar improvement in climate control efficiency and operation.

46

An Engine Exhaust Fired Non-Chlorofluorocarbon Refrigeration and Thermal Storage System--Rocky Research, 1598 Foothill Drive, P.O. Box 61800, Boulder City, NV 89006-1800; (702) 293-0851
Mr. Paul Sarkisian, Principal Investigator
Dr. Uwe Rockenfeller, Business Official
DOE Grant No. DE-FG03-93ER81626
Amount: $74,701

Typical truck-trailer refrigeration units currently use either the chlorofluorocarbons (CFCs) R-12, R-500, or R-502, or hydro CFC (HCFC) R-22 as a near term replacement. All of these refrigerants contribute to the ozone depletion problem. Because the CFCs are scheduled for a complete phaseout by the year 2000 and HCFCs (R-22) by the year 2020, it is imperative for the food industry, trailer refrigeration industry, and the consumer, that an environmentally benign alternative system be developed. The objective of this project is to develop a method of providing environmentally benign refrigeration using solid-state ammoniated complex compound refrigeration that can be driven by either the truck diesel exhaust or a small backup diesel heater during idling. The savings in energy consumption, the non-CFC environmentally friendly aspects of the system, and the adaptability of the technology to present production techniques make the system well suited to future widespread use. Planned for Phase I is a study and proof-of-concept laboratory testing of up to three candidate complex compounds to determine their potential for refrigeration and thermal storage for operation in the -20°F to 35°F temperature range. Based on these results, a preliminary system specification and design including equipment mass, size, and overall performance, as well as detailed requirements for all components and system circuiting, will be generated.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is expected that Phase I will show that the complex compound refrigeration and thermal storage system is competitive with typical truck-trailer refrigeration units on a performance, weight, size, and cost basis. Efficiency of the complex compound system is expected to be better than a conventional unit at -20°F when fired by diesel fuel, and dramatically better when fired by waste heat from the truck's diesel engine exhaust.

47

An Electric Vehicle Climate Control System Using Vapor Compression for Heating and Cooling--Solar Car Corporation, 1300 Lake Washington Road, Melbourne, FL 32904;
(407) 254-2997
Dr. Douglas A. Cobb, Principal Investigator
Dr. Robert A. Adams, Business Official
DOE Grant No. DE-FG0593ER81601
Amount: $73,850

Recognizing the underlying motivation in electric car design to conserve energy and the necessity for effective climate control, this project offers a technical approach to minimize energy requirements for both air conditioning and heating to extend the range of an electric vehicle. Currently available compressor systems are inadequate in efficiency, size, and weight. This technical problem will be investigated by optimizing the coefficient of performance (COP) of the air conditioning system through a custom-engineered compressor known as the orbital vane refrigerant compressor. This compressor is a highly efficient anti-friction non-contact sealing rotary vane machine that has fewer moving parts than conventional compressors and operates on a variety of refrigerants, including those that are ozone-safe. Ease of compressor production is an extremely important market factor within the context of the development of a cost-competitive electric vehicle air conditioning system, and is achievable. The overall concept of this project is to match the orbital vane refrigerant compressor with an electric motor of the same speed and torque characteristics for an optimum COP. This offers the ability to build a light-weight unit of high efficiency occupying the smallest space possible with both cooling and heating (heat pump) capabilities. This unit could be coupled with solid state heating elements to provide a climate control system for electric vehicles superior to any system now available. The Phase I investigation will include the specification determination, design, analysis, and preparation of detailed engineering drawings for the compressor, and the fabrication of the prototype compressor.

Anticipated Results / Potential Commercial Applications as described by the awardee: The heart of this project is the light weight, high efficiency compressor. The orbital vane compressor can be manufactured at relatively low cost on conventional production machine tools, and contains about half the parts of conventional compressors. For these reasons, the project offers a reliable and effective base upon which to develop and produce a low energy- budget and environmentally friendly electric vehicle climate control system that will extend the range of electric vehicles and improve marketability.

CHEMICAL PRODUCTS FROM BIOMASS

48

Production of Carbon Materials from Biomass--Advanced Fuel Research, Inc., P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. Chad M. Nelson, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG05-93ER81593
Amount: $74,929

Lignin is the most abundant renewable aromatic polymer. Given the relatively low cost, high abundance, and renewable nature of this resource, it is not surprising that many attempts have been made to develop higher value products from lignin. Carbon materials have a much higher added value than almost any other product which can be produced from lignin. This Phase I project suggests that an appropriate modification of the composition of lignin-derived pitch could greatly enhance its suitability as a precursor material for carbon fibers and other carbon materials. Relatively high yields of alkyl substituted, oxygen reduced tars can be produced from lignin pyrolysis followed by secondary catalytic treatment of tars over an alumina bed. Lignin-modifying enzymes can reduce, depolymerize, and/or demeth(ox)ylate lignin-like materials. Completion of this project through Phase II would result in a process tailored toward the production of mesophase pitch from lignin, an optimized product slate, a quantitative model relating tar properties to process conditions, and on-line Fourier Transform-Infrared (FT-IR) diagnostics for process control.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful completion of the project through Phase II would result in a design for a process to produce liquid precursors for carbon materials production from lignin. The results would also include a quantitative model which relates the lignin tar composition to the time temperature history of the tar after its formation (to be developed in Phase II) and the further development of on-line FT-IR diagnostics which could be used for process control. All of these results would greatly benefit ongoing efforts to increase the utilization of lignin to replace fossil fuel derived feedstocks.

49

Enzyme Catalyzed Polymerization of Chiral Acids in Organic Solvents--Metabolix, Inc., P.O. Box 695, Cambridge, MA 02142; (617) 262-9235
Dr. Simon F. Williams, Principal Investigator
Dr. Simon F. Williams, Business Official
DOE Grant No. DE-FG02-93ER81526
Amount: $75,000

The objective of Phase I is to design a non-aqueous enzyme system that can convert conventional feedstocks into specialty chemicals. Specifically, this effort involves identifying a non-aqueous medium that is compatible with an enzyme known as a polymerase. The latter can convert simple hydroxyacids into industrially important thermoplastics and specialty chemicals. The design of a non-aqueous polymerase system will allow the formation of new materials, known as polyhydroxyalkanoates (PHAs), from conventional feedstocks. In addition, this system will allow the optical resolution of a class of 3-hydroxyacids. The new process will be environmentally friendly and provide an energy efficient method for the production of specialty chemicals.

Anticipated Results / Potential Commercial Applications as described by the awardee: A non-aqueous polymerase system will provide new PHA materials from conventional feedstocks. These materials will find application as thermoplastics and specialty chemicals. Potential uses could include, but are not limited to, the following: intermediates for the syntheses of pharmaceuticals, agrochemicals, flavors and fragrances; toner for ink cartridges; coatings for paper; capsules to control drug release; surgical sutures; wound care devices, and bone plates.

BIOMASS ELECTRIC POWER TECHNOLOGY

50

A Novel Hot Gas Cleanup System for Biomass Power Technology--LSR Technologies, Inc., 898 Main Street, Acton, MA 01720; (508) 635-0123
Dr. Leo A. Smolensky, Principal Investigator
Mr. S. Ronald Wysk, Business Official
DOE Grant No. DE-FG02-93ER81613
Amount: $75,000

Among the viable contenders for new generation power sources is biomass power. Advanced biomass power systems typically incorporate aeroderivative turbines which have very stringent requirements with regard to alkali and particulates. Removal of these impurities from gasifier producer gas prior to feeding to a gas turbine combustor has been identified as one of the major technical challenges in the DOE Biomass Power program. No existing separation system can be used for this program without extensive modifications. The planned separation concept utilizes the basic principles of a core separator which has been recently developed for treating low temperature flue gas. Its features and benefits are that it can function as a primary and secondary filtration system, it is simple, reliable, and capable of handling high solids concentrations, is insensitive to blinding, and is lower in capital and operating cost than filter devices. Phase I will include extensive testing at the pilot scale level using a simulated biomass gasifier producer gas.

Anticipated Results/Potential Commercial Applications as described by the awardee: New and improved techniques are needed to reduce alkali/particulate levels from a biomass gasifier producer gas. The simplicity and performance of the proposed separator will make it attractive for this application. It will be capable of 99% retention of 3 μm particles at 540°C (1000°F). If the goals outlined in this program can be achieved, aeroderivative turbines for biomass power systems may run at optimum efficiency with adequate turbine life.

ADVANCED WINDOW AND GLAZING TECHNOLOGIES

51

An In-Situ Tester for Seal Integrity of Multiple Pane Windows--Aerodyne Research, Inc., 45 Manning Road, Billerica, MA 01821; (508) 663-9500
Dr. Paul L. Kebabian, Principal Investigator
Dr. Charles E. Kolb, Business Official
DOE Grant No. DE-FG02-93ER81522
Amount: $74,954

In-situ performance characterization of advanced glazing materials could help manufacturers and building inspectors in the implementation of utility incentive programs. One of the more widely used advanced glazing materials is the multiple pane window, in which the space between the panes is sealed and backfilled with a dense gas of low thermal conductivity, such as argon. If this gas is absent, due to leakage or improper filling, the thermal insulation quality of the window is compromised. When a seal failure occurs, some or all of the backfill gas will be replaced by air, which contains 21% oxygen. Oxygen can be detected by optical spectroscopy, using its absorption line spectrum in the 760 nm region. Currently laser sources are used for spectroscopic oxygen detection. But these devices are expensive, complex, and not suitable for field use. In this project, a gas discharge lamp will be used to provide a spectral line close to an oxygen absorption line. The spectral line will be split by a magnetic field into polarized components, one of which coincides with the oxygen line, using the Zeeman effect. Phase I of this project aims to determine the optimum magnetic field, complete the design of the polarization selector used for differential absorption measurement, and demonstrate the sensitivity to oxygen of a system using these components.

Anticipated Results / Potential Commercial Applications as described by the awardee: The proposed oxygen sensor will enable the nondestructive determination of leakage of the backfill gas in multiple pane windows. This sensor is expected to be inexpensive, reliable, and usable by operators with minimal training. A similar oxygen sensor could also be used in many of the industrial applications where ambient oxygen levels must be monitored to insure the safety of personnel.

52

Flexible Electrochromic Window Materials Based on Poly(diphenylamine) and Related Conducting Polymers--Ashwin-Ushas Corporation, Inc., 206 Ticonderoga Boulevard, Freehold, NJ 07728; (908) 462-1270
Dr. P. Chandrasekhar, Principal Investigator
Dr. P. Chandrasekhar, Business Official
DOE Grant No. DE-FG05-93ER81631
Amount: $74,976

Electrochromic window materials with low power consumption and high and reversible cyclability have received much attention for potential uses in energy conservation and lighting control in commercial buildings, houses, and automobiles. In contrast to systems such as WO_3 (tungsten trioxide), conducting polymers (CPs) have received increasing attention due to their greater potential for tailorability and more variables for system improvement. The Phase I work will use stable prototype devices based on poly(diphenylamine) and poly(diphenylbenzidine), two such CPs with demonstrated cyclability through 10,000 cycles that have already been developed. These devices are thin, flexible, hermetically sealed, very inexpensive, and use little power. In contrast to other CPs, these two have the desirable color changes of glass-transparent to opaque green-black. The Phase I investigation will seek to bring these further to a level of commercial viability, especially with respect to extended cycling and large-area use, using a number of novel approaches. The target will be flexible, thin electrochromics "clipped on" to existing window systems and discarded after useful life. The approaches used will attack improvements in polymer structural properties, morphology, and reprocessing, and incorporation of new features in device design, including better potential control, special transparent gelled electrolytes, superior gaskets and seals, and effective methods for addressing resistance problems in the transparent conducting substrates for large-area use.

Anticipated Results / Potential Commercial Applications as described by the awardee: A technology for electrochromic control of window transparency with applications in large commercial buildings for energy conservation, in car windshields, and in houses could become available. The clip-on, disposable design will permit retrofitting rather than replacement. Display devices are another potential use. Apart from this, processible conducting polymers have use in infrared/radar signature control, electromagnetic interference shielding, and other areas.

53

A High Performance Window Edge and Frame Design--Creare, Inc., P.O. Box 71, Hanover, NH 03755; (603) 643-3800
Mr. William E. Nutt, Principal Investigator
Dr. Paul H. Rothe, Business Official
DOE Grant No. DE-FG02-93ER81536
Amount: $74,973

An innovative high performance window edge and frame design will be developed. The project objectives are to demonstrate that the design is feasible from heat transfer, structural, and economic perspectives. Additionally, the design must be compatible with standard architectural and building practices, be compatible with inert gas filling, low E glass, multilayer windows, and have a life span and durability equal to or in excess of the current market standard. Analyses will be performed to determine the heat transfer and structural characteristics of the design. A sample section will be built and tested to confirm the heat transfer analysis. A viable fabrication process will be identified to determine the economic feasibility of the design. It is fully anticipated that Phase I will demonstrate the feasibility of the concept. When fully developed and commercialized, the high performance edge and frame design will be valuable for both the residential and commercial applications in new and in retrofit situations. It will reduce energy consumption for the Nation at large.

Anticipated Results / Potential Commercial Applications as described by the awardee: The anticipated results are a high performance window edge spacer and frame design and identification of an economically viable means to manufacture the windows. Commercial applications exist wherever insulating windows are desirable.

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Electrochromic Glazings Deposited by High Rate Processes--EIC Laboratories, Inc., 111 Downey Street, Norwood, MA 02062; (617) 769-9450
Dr. Stuart F. Cogan, Principal Investigator
Dr. A. C. Makrides, Business Official
DOE Grant No. DE-FG02-93ER81609
Amount: $75,000

A project to develop variable solar transmittance coatings for architectural glazing applications is planned. The transmittance modulation is based on the electrochromic response of transition metal oxide films, electrochemically reduced and oxidized using lithium ion insertion and extraction. The coatings will be multi-layer, thin film structures containing two transparent electronically conducting films, two complementary electrochromic materials that color and bleach synchronously during optical switching, and an oxide ion conducting layer. All layers in the coating are metal oxides. The materials and coating structure are chosen to produce electrochromic glazing capable of multi-cycle switching over many years under the harsh environmental conditions of glazing applications. The specific innovations planned are the use of materials and deposition protocols that will allow electrochromic coatings to be deposited by sequential direct-current (DC) magnetron sputtering at the high rates required for commercial viability in large coating operations. Of particular significance are innovations that will allow DC sputtering of lithium ion (Li^+) conducting oxides and electrochromic materials that are reduced in vacuo with the appropriate amount of lithium for electrochromic switching. The objectives of the Phase I project are the demonstration and characterization of Li^+ conducting oxides deposited by reactive DC sputtering and the incorporation of these oxide films into electrochromic devices. The Phase II project would focus on optimization of optical switching, environmental stability, and scaling to large areas.

Anticipated Results / Potential Commercial Applications as described by the awardee: A successful project would result in the development of variable solar transmittance glazings that have the optical switching performance and environmental stability necessary for architectural applications, and that can be deposited at the high deposition rates required for commercial fabrication. Commercial opportunities for successful electrochromic glazings are significant, encompassing applications in atria, passive solar dwellings, automobiles, and office buildings.

55

Development of Advanced Window Materials Based on Conducting Polymer/Sol-Gel Ceramic Composites--Gumbs Associates, Inc., 11 Harts Lane, East Brunswick, NJ 08816; (908) 257-9049
Dr. Guang-Way Jang, Principal Investigator
Dr. Ronald W. Gumbs, Business Official
DOE Grant No. DE-FG05-93ER81632
Amount: $75,000

The planned research concerns the development of conducting polymer/sol-gel ceramic composites as durable electrochromic coatings for energy-conserving applications such as day lighting and thermal control. Conducting polymers provide an attractive opportunity for fabricating smart windows because of the interesting electrochromic phenomena associated with the redox (doping) processes of these polymers. The commercial applications of these materials as electrochromic coatings, however, are, at present, limited by the poor cycle lifetimes and poor processibility of polymer coatings. Phase I will investigate the novel composite materials incorporating conducting polymers and transparent sol-gel glass for improving mechanical and optical properties of electrochromic coatings to be used to fabricate advanced smart window materials and systems. The utilization of sol-gel reaction solution as carrier medium provides a unique opportunity to prepare electrochromic coatings from conducting polymers which commonly suffer from poor processibility. Theoretical quantum chemical modeling studies will be carried out in order to enhance the understanding of correlation between electronic structure of the conjugated polymers and the electro-optical properties exhibited by them.

Anticipated Results / Potential Commercial Applications as described by the awardee: The results of these investigations will be directly applicable to many key windowing devices currently in use and to meet the future challenges of optical material design. The commercial applications of conducting polymer/sol-gel ceramic composites include electrochromic displays, anticorrosion coatings, biosensors, and rechargeable batteries.

56

Liquid Crystal Smart Windows--Meyer and Lonberg Associates, 70 Buckminster Road, Brookline, MA 02146; (617) 277-0394
Dr. Franklin Lonberg, Principal Investigator
Dr. Franklin Lonberg, Business Official
DOE Grant No. DE-FG02-93ER81614
Amount: $74,780

This Phase I project will study the use of cholesteric liquid crystals to make smart windows which change easily between transparent and reflective for controlling the transmission of solar energy. The objective of this effort is the demonstration of the feasibility of using cholesteric liquid crystals in this way. The basic mechanism for a feedback stabilized, light modulated reflector which transmits a constant light flux independent of changes in the incident light intensity will be explored. Also, measurement of the broadening of the optical reflection band of a cholesteric liquid crystal caused by a spatial gradient in the pitch of its periodic helical structure will be made, and the material requirements involved in optimizing the performance of cholesteric reflectors will be investigated.

Anticipated Results / Potential Commercial Applications as described by the awardee: Modulated reflection windows are superior to the other techniques for control of solar radiation because they can both block incoming radiation without heating as absorbing windows do, and also continue to transmit images, which scattering type windows do not, thereby maintaining the window's aesthetic function. Several final forms of the cholesteric smart windows are envisioned: a light control window which changes from transparent to reflective in response to strong light, a field control window which can be switched from reflective to transparent by the application of a voltage, and a thermal control window in which the liquid crystal would change from transparent to reflective when it becomes warm.

57

Novel Spectrally Selective Window Films Based on Multiplexed Holography-- Physical Optics Corporation, 20600 Gramercy Place, Suite 103, Torrance, CA 90501; (310) 320-3088
Dr. Gajendra Savant, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-93ER81582
Amount: $74,935

It is planned in Phase I to develop advanced multiplex holographic films (MHF) which can provide the advantages of daylighting and solar control simultaneously. These films will utilize new holographic techniques for beam shaping and reflections of the near ultraviolet (UV) solar spectrum. The resulting MHFs will be spectrally selective with high transmissions in the visible spectral range and with high reflectivity in both near infrared and near UV spectral regions. In addition the beam shaping capability of the planned MHFs will provide most efficient and uniform daylighting without negative tradeoffs. They can also be recorded onto flexible substrates and then adhered to a single glazing. The MHFs can be produced using cost-effective manufacturing techniques leading to the most efficient and economical window films with high commercialization potential.

Anticipated Results / Potential Commercial Applications as described by the awardee: The MHF technology will improve energy efficiency of many industrial installations, office buildings and residential housing independently of their orientation in most areas of the United States of America. The MHFs will also be applicable to automotive windows leading to the reduction of air-conditioning loads. Thus the benefits of this technology include both energy savings and pollution reduction.

58

The Feasibility of Using Squeeze Roll Coating to Form Sol-Gel Derived Layers for Switchable Electrochromic Windows--Sage Corporation, P.O. Box 278, Piscataway, NJ 08855; (908) 932-3300
Dr. Frank B. Ellis, Jr., Principal Investigator
Mr. John E. Van Dine, Business Official
DOE Grant No. DE-FG05-93ER81545
Amount: $74,571

To attain the potentially vast energy saving and environmental benefits of electrochromic (EC) smart windows, an economically and technically viable manufacturing technology must be achieved. The sol-gel technique offers distinct advantages over the commonly used vapor deposition techniques as a core film deposition method for these multilayer structures. All inorganic lithium-based solid state smart window devices have been fabricated on glass substrates using the sol-gel dip coating method to grow the ion conductor layer and other layers of this device. However, conventional dip coating also has its limitations in a production environment. Phase I will combine the sol-gel technique with squeeze-roll coating as an alternate coating technique which combines the advantages of dip coating with the potential benefits of a continuous line suitable for mass production of the multilayer smart window structures. The specific objective in Phase I is to test the feasibility of using this "roll-gel" coating to obtain films of an EC electrode material on up to 18 in. wide glass substrates which are sufficiently thin and uniform in thickness to provide good EC device performance. For Phase I, the films will be the EC material tungsten trioxide. A further objective is to design a roll-gel continuous line for construction and development in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: A technically enabling and economically viable process is anticipated for manufacturing EC smart windows for vast markets in commercial and residential buildings, automotive and other transport vehicles, and in smaller markets, in large area displays and a variety of other electronic products.

EDUCATIONAL TECHNOLOGIES

59

A Laboratory/Field Workstation for Science Education--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Ms. C. Jean Bustard, Principal Investigator
Dr. Judith A. Armstrong, Business Official
DOE Grant No. DE-FG02-93ER81585
Amount: $75,000

A step toward being number one in mathematics and science education by the year 2000 (America 2000 goal) and maintaining reasonable school budgets can be made by introducing a low cost system which will bring the state-of-the-art technology into the high school laboratory. The planned laboratory workstation addresses this need, by taking the state of the art tools available for researchers and integrating them into a cost effective, easy to use, modular system for use in high school laboratories. The system consists of a low cost hand held data acquisition and logging system, a user selectable sensor array, and software for downloading data to a personal computer for analysis. The Phase I project will develop a plan for integrating this workstation into the school curriculum. The precise specifications for the hardware and software will be developed through a series of meetings with educators. With these specifications and significant microcontroller experience, the proof-of-concept hardware and software will be developed. This system will then be field tested in a high school laboratory. The information gathered in Phase I will define the approach to curriculum integration that will be implemented in Phase II. Feedback from the field testing process will be used to refine and augment the design into a prototype instrument during Phase II. By actively addressing curriculum integration along with field tested hardware, the system will be ready for commercialization in phase III.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned system will be integrated into the school science curriculum following the plan developed in Phase I. The system will be a significant step forward in providing "hands on" experimentation with "real-world" tools to more students. The commercial market for the system would include all branches of science education in high schools and phase III refinements will expand the market into middle schools and colleges.

60

Interactive Computer Simulations to Demonstrate the Behavior of Gases, Liquids, and Solids on an Atomic and Molecular Basis–Advanced Fuel Research, Inc., P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. David F. Hamblen,, Principal Investigator
Mrs. Sally Solomon, Business Official
DOE Grant No. DE-FG05-93ER81592
Amount: $74,998

Effective teaching and learning at all levels of education is enhanced by demonstration equipment that relates text book concepts to physical observations. Not only does the teacher become more effective in his or her ability to explain a phenomenon, but the triggering of interest and enthusiasm by students is generally more dramatic. Effective and comprehensive demonstration models of the dynamic nature of atomic and molecular interactions do not exist. This is especially true of models with sufficient mathematical and scientific integrity to permit the teacher to modify a specific interaction parameter and show the system's response. The beauty and power of kinetic theory is hidden from almost every high school student because of the mathematics or computing power required for a true understanding. Several techniques combined in a Monte Carlo fashion to improve the efficiency of these calculation have recently been demonstrated. A simulation performed over 4000 particles on a small one million instructions per second computer performed 250 times faster than similar calculations on a CRAY 1. These and other techniques will be employed to expand the applicability of Monte Carlo modeling and to include attractive and chemical interactions to demonstrate a wide selection of chemical and physical processes such as diffusion, phase changes, viscosity, heat transfer, and gas phase chemistry. The objective of Phase I is to explore and demonstrate the range of processes which can be exhibited. Phase II will implement a wide range of demonstrations. Phase II should result in a marketable computer demonstration. A properly done interactive video display could tie together the phenomena at a most elementary, observational level, while retaining the integrity and power to continue to effectively instruct through the undergraduate level.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is believed that the demonstration product will provide an excellent tool for high school and undergraduate students to build the concepts on which physical and chemical phenomena are based. The students' understanding and interest in science will be improved as will the teachers' understanding needed to further enhance teacher/student communication. Such a tool should increase the number and competence of students entering science and engineering disciplines.

61

An Intelligent Tutor to Advance Integrated Mathematics Curricula in Middle and Secondary Schools--Owen Research, 2525 Arapahoe Avenue, Suite E4-262, Boulder, CO 80302; (303) 441-9027
Dr. Robert B. Owen, Principal Investigator
Dr. Robert B. Owen, Business Official
DOE Grant No. DE-FG03-93ER81588
Amount: $74,482

Educators throughout the country face major challenges such as teaching subjects and thinking skills that will prepare students for today's global economy and maintaining learner interest. The education community itself is exploring pioneering approaches such as the integration of subjects rather than the traditional isolation of subject-matter into boxes. A case-based reasoning (CBR) intelligent tutor will be explored for secondary teachers that will address and should significantly alleviate these two problems by using curriculum integration. A tool will be developed to enable teachers both to utilize their years of experience and their development of materials unique to the specific educational situation and to maintain learner interest and develop problem solving skills. By using an integrated curriculum program developed by a team of teachers over ten years as a model for an expert system, teachers nationwide will be assisted in using this approach in classrooms. Memory organization packets will be used to represent concepts and contexts (cases) in a hierarchical structure optimized for educational CBR and fuzzy logic to modify the cases. Phase I will investigate the concept that an existing program integrating mathematics, biological and physical sciences, and language arts for a secondary class can be formulated using CBR and artificial intelligence methodology as an aid to teachers. Phase II will prove the system in already identified secondary schools that have Apple Macintosh Plus computers available to teachers.

Anticipated Results / Potential Commercial Applications as described by the awardee: An intelligent tutor teaching aid for advancing integrated mathematical curricula should result from this project. There is commercial application in corporate training of individuals and teams for technical operations--computer operation, local area networking, information processing, and fast-response technical functions.

62

EarthLab: A Televisualization Environment for Learning Through Cooperative Problem Solving in Earth Science Education--Ross Computational Resources, 318 North Franklin Avenue, Madison, WI 53705; (608) 238-8949
Dr. Edward J. Hopkins, Principal Investigator
Ms. Ruth A. Ross, Business Official
DOE Grant No. DE-FG02-93ER81562
Amount: $75,000

This project deals with the creation of "EarthLab," a model-based visually rich interactive learning environment for earth science education. It is built on a system architecture designed to support internetworking that would facilitate an integrated curriculum, problem solving, and cross-disciplinary application of knowledge and skills. EarthLab would encourage a joint effort by both students and teachers, leading to increased understanding of concepts and issues, procedural competence, and enthusiasm for science. This effort could enrich learning environments for all students by providing valuable support for innovative approaches to science education while attempting to remove barriers to learning including those experienced by minority students, female students, and students with different learning needs. An advisory group of dedicated educators representing both university educational research and K to 12 teaching backgrounds will be closely involved in the Phase I research. A book-length document describing specific objectives for learner behavior will be developed as will the functional requirements for educational software environments to facilitate these behaviors, and the design of an EarthLab that would meet those requirements. A limited version to be set up at several locations accessible to teachers and students (including those with disabilities) will be implemented for their experimentation and evaluation. The emphasis in this pilot project will be on the use of meteorological case study and real-time weather data to showcase an environment supporting the visual investigation of aspects of climate that relate to phenomena from all areas of earth science, which in fact have links to other areas of science and mathematics as well, and to demonstrate the power of such an interactive and integrated environment to involve students and teachers in the joy of scientific exploration.

Anticipated Results / Potential Commercial Applications as described by the awardee: EarthLab will provide important support for the earth science curriculum and for schools wanting to evaluate the benefits of an integrated science course with creative use of advanced technology. Initial response to the project description indicates that it might have considerable commercial potential as a product for schools, libraries, and science museums. Its power and reasonable cost will create the opportunity for it to enrich science education for a wide base of learners.

63

An Intelligent Tutoring System for Statistics--Statistical Sciences, Inc., 1700 Westlake Avenue North, Suite 500, Seattle, WA 98109; (206) 283-8802
Dr. Deborah Donnell, Principal Investigator
Mr. Matthew Schiltz, Business Official
DOE Grant No. DE-FG03-93ER81649
Amount: $74,697

Intelligent tutoring systems (ITSs) promise improved quality of education at reduced cost: they could provide the benefits of one-on-one tutoring without the personnel cost. However, this potential has not yet been realized. A new type of ITS that addresses a fundamental flaw in traditional approaches is planned. The outcome of any teaching intervention is uncertain, and the state of the students knowledge is uncertain. This approach explicitly models this uncertainty, providing a more accurate model of the student, and enabling the tutoring system to learn from experience. In Phase I this ITS will be applied to college level statistics education. Students need a good grasp of statistical concepts to read and critique scientific literature, plan and carry out projects involving data collection, understand and practice scientific method in research, and make decisions in the face of uncertainty. However, there is widespread concern that statistics is not being taught effectively in the American education system. An ITS, providing one-on-one tutoring, could transform statistics education.

Anticipated Results / Potential Commercial Applications as described by the awardee: The results of this project have the potential to move ITS technology to the point where it can fulfil its commercial potential. Statistics is an educational area of growing priority, and colleges will be well placed to take immediate advantage of an ITS in statistics.

64

Living on Earth: A Multimedia-Based Learning Environment for the Earth Sciences--Videodiscovery, Inc., 1700 Westlake Avenue North, Suite 600, Seattle, WA 98109; (206) 285-5400
Dr. D. Joseph Clark, Principal Investigator
Dr. D. Joseph Clark, Business Official
DOE Grant No. DE-FG03-93ER81651
Amount: $74,978

A multimedia-based learning environment for 8-12th grade earth science education will be created on CD-ROM and videodisc. The system consists of a visual database delivered in both analog and digital formats, detailed lesson plans, and textual support materials. The system will permit the gradual integration of new, thematic, interdisciplinary approaches to earth science teaching into existing discipline-bound classrooms. In the Phase I research a prototype videodisc and CD-ROM will be used to test six representative earth science lessons in 8th, 10th and 12th grade classrooms. In Phase II a comprehensive multimedia collection will encompass geology, astronomy, oceanography, and meteorology.

Anticipated Results / Potential Commercial Applications as described by the awardee: The product would be distributed to secondary schools nationwide. The comprehensive visual database along with lessons will be customized to local curricular needs and improve the teaching of earth science. The wide utilization of the product will facilitate the shift to an interdisciplinary, application-oriented approach. Additional software products that are correlated to the Living on Earth multimedia product will be developed by third party vendors.

65

A Virtual Environment Workstation for Energy Education--W.W. Gaertner Research, Inc., 140 Water Street, Norwalk, CT 06854; (203) 866-3200
Mr. William M. Hawkins, Principal Investigator
Mr. Francis J. Musso, Business Official
DOE Grant No. DE-FG05-93ER81516
Amount: $72,974

The planned project to develop a Virtual Environmental Workstation for Energy Education (VEWEE) will include demonstrating viability of a virtual reality workstation for science and mathematics educational purposes using multisensory feedback. The VEWEE system will provide computer generated images in a virtual environment as well as audio and tactile feedback. As part of the Phase I concept definition phase, two roundtable discussions with the Cooperative Precollege Educational Program at DOE's

Continuous Electron Beam Facility (CEBAF) in Newport News, Virginia will be conducted. These roundtable discussions will focus on defining courseware (software) for the VEWEE based on the needs of the CEBAF educational program staff and CEBAF selected university partners. The ultimate goal of this development project is to provide an affordable virtual reality workstation and useful courseware that can be used at the middle and secondary school levels.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned VEWEE system should generate synthetic environments that can be used for educational programs, training/simulation systems, and telepresence systems for robotic remote operations.

HUMAN GENOME

66

A High Spatial Resolution Spectrograph for DNA Sequencing-- Chromex, Inc., 2705-B Pan American NE, Albuquerque, NM 87107; (505) 344-6270
Dr. Cathy D. Newman, Principal Investigator
Mr. Eugene Watson, Business Official
DOE Grant No. DE-FG03-93ER81635
Amount: $74,849

If the human genome project is to be successful, much more rapid DNA sequencing will be required. It is estimated that present technology is 100-500 times too slow to permit sequencing of the entire human genome by the original projected completion date of 2005. Currently, the most successful technology employed for large scale DNA sequencing involves real-time, four color, fluorescent line imaging during the electrophoresis process (i.e., the ABI 373A DNA sequencer). This basic technology can probably be scaled to significantly higher levels and is likely to remain the method of choice for future DNA sequencing. Indeed, a number of research groups have been developing faster fluorescence DNA sequences. Although great strides have been made in reducing electrophoresis times (10-20 fold), future gains in throughput will primarily depend on increased multiplexing. Such high throughput instruments will require a detection system with hundreds of spatially resolved channels. In Phase I a completely new concept in high spatial resolution spectroscopy will be tested. The high spatial resolution performance will be achieved by employing a radically different approach to the design of a spectrograph. Such a spectrograph, when combined with a charge coupled device array detector, will produce a system capable of rapidly recording spectral signatures from more than 300 spatial locations.

Anticipated Results/Potential Commercial Applications as described by the awardee: In addition to DNA sequencing, the capability for high spatial resolution and simultaneous acquisition of spectral data make many new applications possible. Many of these applications are relevant to the Human Genome Project such as multi-color scanning of restriction digests, multi-wavelength fluorescent microscopy (with no color registration problem), and highly multiplexed fluorescent enzyme-linked immunoassays.

67

Non-Radioactive Detection Systems Based on Enzyme Fragment Complementation-- Collaborative Research, Inc., 1365 Main Street, Waltham, MA 02154; (617) 487-7979
Dr. Peter Richterich, Principal Investigator
Dr. Gerald F. Vovis, Business Official
DOE Grant No. DE-FG02-93ER81608
Amount: $75,000

Assays based on DNA hybridization are very commonly used in molecular biology, clinical diagnostics, and the Human Genome Project. However, efficiency and sensitivity of hybridizations are often limited by non-specific binding of probe molecules or detection system components to the target DNA or membrane supports. Detection methods for extremely sensitive, reliable, background-free detection in hybridization-based assays will be developed in this project. The system will be based on two neighboring hybridization probes, each labeled with one subunit of alkaline phosphatase. Individual subunits of alkaline phosphatase are inactive, and non-specific binding of hybridization probes to target DNA or membrane support will therefore not lead to background noise. Upon binding to two probes next to each other on the target DNA, the two enzyme subunits can combine and form the active dimeric enzyme which can be detected with chemiluminescent or colorimetric substrates. Increased hybridization specificity results from the necessity of two probes to hybridize next to one another. In Phase I the feasibility and potential of such binary detection systems will be demonstrated. The conditions for generation, purification, storage and use of subunit-labeled oligonucleotide probes will be defined and optimized. Finally, the binary detection systems will be used for chemiluminescent multiplex sequencing. The extension of protocols with binary enzyme-labeled probes to a large variety of other applications in molecular biology and clinical diagnostics is intended to take place in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: Systems for fast, background-free, extremely sensitive detection in hybridization based assays will be developed. Kits will be developed for use in Southern blotting, DNA sequencing, multiplex sequencing, and clinical diagnostics. Application of the developed binary detection systems will lead to significantly faster, more cost-effective, and reliable multiplex sequencing and thus help to reach the goals of the Human Genome Project.

68

High Performance Searching and Pattern Recognition for Human Genome Databases--
Paralogic, Inc., 115 Research Drive, Bethlehem, PA 18015-4734; (215) 861-6960
Dr. Douglas J. Eadline, Principal Investigator
Mr. Michael L. Busser, Business Official
DOE Grant No. DE-FG05-93ER81642
Amount: $69,714

The Humane Genome Project has the desired goal of determining the entire human genetic code (DNA) consisting of 3 billion nucleotide bases. Because of the expected size of the genome database(s), new technologies that provide cost-effective and time-effective searching, interpretation, and analysis will be required. One very promising approach tc this problem has been the application of grammars to the "genetic language" as expressed by DNA. In essence, the genetic code can be searched using a genetic grammar. These grammars have been developed using the computer language Prolog on single workstation computers. The approach is called parsing, which is similar to diagramming English sentences as means to determine the grammar, but the grammar is based on biological activity not the English language. With the development of a distributed or parallel Prolog, the opportunity for rapid and concurrent linguistic analysis of DNA sequences using multiple computing elements is possible. Phase I seeks to determine the feasibility of combining n-parallel/Prolog, grammar based searching, and parallel computers as means of efficiently and quickly searching the genome database. By combining these technologies, the colossal human genome information bank can become easily and economically accessible to the pharmaceutical, bio-technical, and academic sectors of the economy.

Anticipated Results / Potential Commercial Applications as described by the awardee: The anticipated result of the combined technologies is the rapid and sophisticated pattern recognition and searching of very large genome databases. The desired result is to make the accumulated knowledge of the genome project usable and accessible throughout the Nation. Commercially, the combined technologies could be developed into nationally funded "searching centers" or purchased by individual institutions for in-house use.

69

Separation Media for DNA Sequencing--Soane Technologies, Inc., 3916 Trust Way, Hayward, CA 94545; (510) 293-1860
Dr. David S. Soane, Principal Investigator
Dr. Zoya M. Soane, Business Official
DOE Grant No. DE-FG03-93ER81497
Amount: $75,000

High-speed, high-throughput DNA sequencing methods rely on electrophoretic separation in very narrow geometries, i.e., micro-capillaries and ultra-thin slabs. As channel dimensions decrease, the separation medium becomes a critical, limiting factor in the speed, accuracy, and reproducibility of DNA fractionations. Conventional, in-situ casting of gels is not well suited for confined geometries, and the current approach of using un-crosslinked polymer solutions has several performance deficiencies, including resolution and reproducibility limitations. This project involves a completely novel separation media concept which combines the desirable performance attributes of crosslinked networks, the loading/unloading feature of dilute polymer solutions, and the user convenience of pre-cast gels. The new approach will utilize discrete, 'smart' gel particles which form a free-flowing pseudo-network under appropriate conditions, and can be readily injected into, and flushed from, narrow capillaries. The feasibility of this technology will be tested in Phase I for DNA separation in a capillary format.

Anticipated Results/Potential Commercial Applications as described by the awardee: Results of Phase I should demonstrate the feasibility of developing a new class of media which greatly improves the resolution and reproducibility of DNA separations, eliminates user involvement in media synthesis, and enables rapid flushing and reloading of separation channels. The key benefits will include higher-speed and higher-throughput DNA sequencing, along with the elimination of user handling of toxic monomers.

BIOTECHNOLOGY: STRUCTURAL BIOLOGY AND MOLECULAR NUCLEAR MEDICINE

70

Technetium-Radiolabeled Somatostatin Receptor Binding Peptides for Imaging Certain Cancers--Diatech, Inc., 9 Delta Drive, Londonderry, NH 03053; (603) 437-8970
Dr. John Lister-James, Principal Investigator
Mr. H. I. Petrocelly, Business Official
DOE Grant No. DE-FG02-93ER81630
Amount: $75,000

Cancer is the second leading cause of death in the U.S. In many cases, early and complete detection is, crucial to a positive prognosis. This often requires detection at a stage when a tumor is too small or too poorly differentiated from normal tissue to be detected by conventional anatomic imaging. Cell surface receptors for the growth hormone release-inhibitor somatostatin (SRIF) are hyper-expressed by a number of cancers. ^{123}I-[Tyrosine^3]-octreotide and ^{111}In-[DTPA] (diethylenetriaminepentaacetic) octreotide are radiolabeled small peptide analogues of SRIF that bind with high affinity to SRIF receptors and have been shown to be extremely useful in detecting certain cancers including small cell lung carcinoma, pancreatic carcinoma, lymphoma, and some breast cancers. However technetium (^{99m}Tc) is the preferred nuclear medicine isotope because it yields greater photon flux per unit of radiation dose delivered to the patient, has a convenient 6 hour half-life, is relatively inexpensive, and is available 24 hours a day from an in-house generator. Therefore a ^{99m}Tc-labeled small, synthetic somatostatin-receptor binding peptide should combine the documented diagnostic efficacy of the ^{123}I and ^{111}In agents with the significant advantages of ^{99m}Tc as the radionuclide. The goal of this project is to develop a nuclear medicine imaging agent that is a ^{99m}Tc-labeled small, synthetic SRIF-receptor binding peptide for imaging SRIF-receptor expressing tumors. To meet these objectives, it is planned to prepare and assay invitro, approximately 20 peptide-chelator conjugates and their rhenium complexes. Furthermore, ^{99m}Tc complexes will also be prepared and tested in animals bearing SSTR-expressing tumors.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful achievement of the goals of this project will provide a non-invasive, rapid, cost-effective diagnostic imaging procedure which will be useful for initial disease staging and in the follow up to therapy of somatostatin receptor expressing tumors with consequent significant positive impact on patient management.

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A Novel Detector for X-Ray Absorption Spectrocopy--InterFET Corporation/RMD, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Mr. James Lund, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-93ER81612
Amount: $75,000

The objective of the Phase I research project is to produce a new type of X-ray detector for use in X-ray absorption spectroscopy (XAS) experiments at synchrotron sources. Present XAS studies are limited by existing detectors. The planned detector system would consist of an array of silicon detectors with the first stage of amplification provided by a junction field effect transistor (JFET) integrated with the detector. The detector array would be capable of high count rates, good energy resolution and would be operated at room temperature. The development of these detectors is straightforward, since a modification of an existing manufacturing process will be used to fabricate them.

Anticipated Results / Potential Commercial Applications as described by the awardee: The device should provide new detection capabilities, will be useful in many X-ray techniques, and will have a large market just in that field. In addition, a new position sensitive X-ray sensor will find a multitude of other uses in research, analysis, and industrial testing.

INSTRUMENTATION FOR OCEAN MEASUREMENTS

72

An Automated and Submersible Optical Sensor for Very-Near Bottom Momentum Characterization--Owen Research, 2525 Arapahoe Avenue, Suite E4-262, Boulder, CO 80302-6720; (303) 441-9027
Dr. Robert B. Owen, Principal Investigator
Dr. Robert B. Owen, Business Official
DOE Grant No. DE-FG03-93ER81589
Amount: $75,000

This Phase I project will develop an automated and submersible sensor that measures very near bottom fluid flows, suspended particulate sizes and concentrations, and momentum exchanges in the coastal ocean environment. Computer-aided speckle interferometry will be used to deduce a two-dimensional flow from speckle patterns of natural particulates. Particulates are measured through long-distance microscopy. The sensor has a temporal resolution of 33 ms over sub-millimeter to meter scales. It provides sea truth data on critical subsurface ocean processes that cannot be measured remotely. The system includes a laser, microprocessor, video cameras, optics, and a recorder. Power requirements are low--the sensor operates while submerged for several months. Power is conserved with neural networks--the sensor senses environmental changes, and samples accordingly. Biofouling and corrosion are addressed through sampling minimization, shutters, and materials such as copper alloys. Feasibility will be verified through hardware tests. Specifically, Phase I will construct a laboratory speckle interferometer that deduces two-dimensional flow fields from natural ocean particulate side-scatter. Both flow and particulate data will be used to train neural networks that recognize environmental changes. A detailed sensor design will be produced that includes power requirements, operational estimates, and biofouling and corrosion counter-measures.

Anticipated Results / Potential Commercial Applications as described by the awardee: This sensor will provide in-situ data on subsurface ocean processes. Modelers find such data critical for understanding the role of ocean and continental shelves in global climate change. The results are relevant to Government and industry alike, since they are affected by the environmental consequences of energy use. Non-research applications include industrial compliance verification, and monitoring of developed and recreational ocean environments.

73

Bistatic Acoustic Turbulence and a Suspended Sediment Profiler--RD Instruments, 9855 Businesspark Avenue, San Diego, CA 92131; (619) 693-1178
Dr. Blair Brumley, Principal Investigator
Mr. Francis Rowe, Business Official
DOE Grant No. DE-FG03-93ER81496
Amount: $ 74,978

This Phase I project is designed to demonstrate the feasibility of developing a bistatic acoustic Doppler current profiler suitable for measuring profiles of three-axis velocity and backscattering intensity over short ranges with high accuracy and spatial resolution at relatively high sampling rates. This instrument will provide mean current and Reynolds stress profiles and turbulent spectra in the bottom boundary layer. The developed product will also be useful for measurements in the near-surface boundary layer if deployed on a tower or submerged structure. If the instrument is suitably calibrated, the backscattering intensity measurements can be used to indicate suspended sediment concentration and flux. When deployed in combination with other instruments such as fluorometers or dissolved gas sensors, fluxes of scalar substances can be measured.

Anticipated Results / Potential Commercial Applications as described by the awardee: An instrument will be developed that will provide mean current and Reynolds stress profiles and turbulent spectra in the bottom boundary layer.

74

An Oceanographic Carbon Dioxide Sensor--Umpqua Research Company, P.O. Box 791, Myrtle Creek, OR 97457; (503) 863-7770
Dr. James R. Akse, Principal Investigator
Mr. John S. Aker, Business Official
DOE Grant No. DE-FG03-93ER81641
Amount: $75,000

The feasibility of a simple atmospheric carbon dioxide (CO_2) sensor for oceanographic deployment will be explored in this Phase I project. Three basic steps are required for sensor operation: membrane equilibration of gaseous and aqueous CO_2, chemical amplification of the concentration of the ionized byproducts of CO_2 dissolution, and specific conductance detection. Atmospheric CO_2 equilbrates across a microporous hydrophobic membrane with an aqueous phase according to Henry's Law. Dissolved aqueous CO_2 then undergoes ionization forming conductive species following the dissociation equilibria. This ionization process is chemically amplified in a recirculating aqueous loop, using water soluble alkanolamines which reversibly react with CO_2, producing conductivity changes corresponding to the atmospheric CO_2 partial pressure fluctuations. These changes are detected using existing flowthrough conductivity measuring devices. The planned sensor offers several advantages including accuracy over the range of atmospheric CO_2 partial pressures, low unit cost, and low weight and power requirements. The system is also expected to be resistant to biofouling and insensitive to the effects of strong relative motion. Additional advantages include simplicity, reliability, ease of use, ease of calibration, ease of automation, operability over a wide temperature range, and capability for unattended operation for periods of up to one year. The method can also be extended to determine dissolved CO_2 in sea water.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that inexpensive, accurate, rugged, and reliable sensor systems, capable of monitoring both atmospheric CO_2 above the ocean surface and dissolved CO_2 in sea water, will be developed. The potential of commercialization of these devices is very good, due to the large number of sensor systems which will be required for gathering "sea truth" and for other global applications.

DESIGN AND APPLICATIONS OF NOVEL MATERIALS

75

On-Chip Ferroelectric Energy Storage Capacitors for Silicon Solar Cells--Advanced Fuel Research, Inc., P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. Jing Luo, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG05-93ER81591
Amount: $74,573

When a solar cell array is designed to power an electric motor car or is used for a space mission, a favorable power-to-weight ratio is important for its energy storage unit. Compared with batteries, the most frequently used energy storage technology, a thin film ferroelectric (FE) capacitor bank, can be of lower cost and yield a higher power-to-weight ratio. In single crystal form, FE materials have superior dielectric properties, such as a large dielectric constant and a high breakdown voltage. Thick films of FE materials have already been used in metal-insulator-metal (MIM) capacitors and are well characterized. The technical challenge in this project will be to grow high quality ferroelectric thin films with large dielectric constant and low leakage current on silicon (Si) substrate. In Phase I, a multilayer MIM capacitor energy storage unit for Si solar cells will be developed. This unit can be deposited at the back of a solar cell wafer to provide on-chip energy storage. This stacked capacitor unit offers ease of fabrication and avoids the various leakage mechanisms found in trench structures. Its structure is compact and should be suitable for wafer scale production (compatible with that for Si solar cells).

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will develop an on-chip multilayer MIM capacitor energy storage unit for Si solar cells. The main advantages of this capacitor energy storage unit are that it can be fabricated on the same Si wafer as solar cells, and it can potentially have a much higher power-to-weight ratio than a battery. In addition to its potential for the primary storage devices for storage cells, the technology could also be used in making small area capacitors in silicon integrated circuits, and in the fabrication of ferroelectric thin-film infrared detectors and memory devices.

76

Porous Aluminum Nitride Part Fabrication to Support Advanced Battery Development--Advanced Refractory Technologies, Inc., 699 Hertel Avenue, Buffalo, NY 14207; (716) 875-4091
Dr. Thomas J. Mroz, Jr., Principal Investigator
Mr. Keith A. Blakely, Business Official
DOE Grant No. DE-FG05-93ER81637
Amount: $74,878

Advanced batteries based on lithium metal sulfide cell technology are under consideration for applications such as the electric vehicle, primarily due to their high energy density capabilities. However, currently available materials limit the reliability of this battery technology for long-term use. In particular, the containment of the electrolyte by an inert separator material is a design-limiting issue. The typical separator fabrication method, involving pressed powder combinations, leads to fragile components that may shift during use, altering the electrical response of the cell. In extreme cases, the entire cell may be shorted. The development of a rigid, porous separator is planned in this project in order to alleviate this reliability issue. Aluminum nitride (AlN), a candidate material for the separator component, will be fabricated into rigid, porous plates using an existing aqueous-based roll fabrication method and specialized sintering technology. Phase I should result in a suitably porous, strong tile that can be impregnated with electrolyte and inserted into the battery cell as an integral unit. Tiles with increased porosity will be developed, based on technology previously used to make tiles for refractory applications. The tile separator concept is expected to greatly improve the reliability of the entire cell, and is also expected to improve the commercial viability of the cell by facilitating a reduction in cell size and weight, and by improving the ability to mass manufacture cells inexpensively.

Anticipated Results / Potential Commercial Applications as described by the awardee: Porous AlN parts produced by this technology will improve the reliability and reduce fabrication problems of lithium metal sulfide batteries. This battery concept is important for the development of electric vehicles. Porous AlN tiles may also be used in specialized filtration applications.

77

Oxide Dispersion Strengthened Silver for Use in High-Temperature Superconductor Composite Wires--American Superconductor Corporation, 149 Grove Street, Watertown, MA 02172; (617) 923-1122
Dr. Gilbert N. Riley, Jr., Principal Investigator
Mr. Edward P. Hamilton, Business Official
DOE Grant No. DE-FG02-93ER81605
Amount: $75,000

The strengthening of High-Temperature Superconducting (HTS) composite wires with Oxide Dispersion Strengthened (ODS) silver is the subject of this project. State-of-the-art HTS composite wires consist of ceramic superconductor filaments encased in a silver (Ag) sheath. For reasons of chemical compatibility and oxygen permeability, silver is the only material that can be used to sheath the HTS. However, the current method of manufacture weakens the Ag sheath, resulting in reduced HTS composite strengths. The low strengths are a major obstacle in the development of HTS wires for applications requiring high strength such as power transmission cables, superconducting magnetic energy storage (SMES), current limiters, and motors. The only known method of increasing the strength of sheath, while maintaining the chemical compatibility and oxygen permeability of Ag is ODS. ODS is currently used to strengthen Ag for relatively low-temperature applications. However, high temperatures are used in the manufacture of HTS composite wires, and little is known about the high temperature characteristics of ODS-Ag materials. Phase I will evaluate novel ODS-Ag materials, in the context of HTS composites processing. Two synthesis routes to form ODS-Ag will be evaluated in Phase I: internal oxidation of a metallic alloy precursor and powder metallurgy. An assessment of the formability and mechanical properties of the ODS-Ag materials produced by each route will be made. Materials produced using the two synthesis routes will be used in statistically designed experiments, based on process conditions similar to those used to fabricate HTS composites. A quantitative expression of the mechanical properties of the novel ODS-Ag materials as a function of the process parameters (temperature, oxygen activity, time, and strain) will be achieved. Phase II will be directed to the fabrication and testing of HTS composites using the optimum sheathing materials.

Anticipated Results / Potential Commercial Applications as described by the awardee: The strengthening of HTS composite wires should accelerate the commercialization of high-temperature superconductors. Applications such as power transmission cables, SMES, current limiters, and motors will become increasingly attractive as the strength of the HTS wire improves. The incorporation of ODS-Ag as the strengthening member will allow the process currently employed to fabricate long lengths of flexible HTS wire to continue in use, without significant modification.

78

Capacitive Energy Storage Using High Surface Area Transition Metal Compounds--Chemat Technology, Inc., 19441 Business Center Drive, #139, Northridge, CA 91324; (818) 727-9786
Mr. Haixing Zheng, Principal Investigator
Ms. Xin Qin, Business Official
DOE Grant No. DE-FG03-93ER81570
Amount: $75,000

High surface area materials have diverse applications, such as for energy storage systems and for catalytic converters. In Phase I, high surface area materials will be prepared using the sol-gel process in Phase I. Various electrically conductive transition metal oxides, nitrides, and borides will be prepared and studied by measurement of their double layer capacitance (which implies energy storage capability per unit area). The effect of the sol-gel processing conditions (such as precursors, concentration, viscosity and drawing speed) on the thickness of the porous coatings will also be determined, while making thick, porous coatings. These coatings would be used as electrodes. An energy storage device will be designed, and its energy storage capability will be evaluated, based on the use of these new sol-gel derived electrodes. The experimental results will be used to optimize the process in order to achieve the best energy storage technology.

Anticipated Results / Potential Commercial Applications as described by the awardee: Potential applications include many where batteries are now used, especially for high pulse power. If this project is successful, the sol-gel process will provide a technique of broad utility to make high surface area materials that can be used as electrodes for capacitive energy storage. Capacitators could be employed in a hybrid energy storage system with batteries, for electric vehicle propulsion systems. They could also store electricity to maintain the memory of components of microprocessor-based systems during an interruption of primary power. High surface area materials made by the same process might also be useful in making catalytic converters.

79

Lubricious-Surface Silicon-Nitride Rings for High-Temperature Tribological Applications–Colorado Engineering Research Laboratory, Inc., 1500 Teakwood Court, Fort Collins, CO 80525; (303) 484-5940
Mr. Frank M. Kustas, Principal Investigator
Dr. Paul J. Wilbur, Business Official
DOE Grant No. DE-FG03-93ER81504
Amount: $74,898

Frictional losses account for a large percentage of the total mechanical power loss in engines. Therefore, sliding surfaces with low friction, high wear resistance, and long lifetimes represent an enabling technology for future transportation systems. This project will investigate an entirely new class of ceramic-matrix-composite (CMC) rings and cylinders, with a graded distribution of ceramic compounds near the sliding-wear interface. The selective ceramic reinforcements will convert to low-friction and low-wear lubricious oxides during high-temperature air exposure. Long-wear-endurance lifetimes of the CMC surfaces will result, due to the self-lubricating, replenishable nature of the reinforcements which are incorporated in the matrix to large depths. Phase I will demonstrate innovative fabrication methods that include: (1) centrifugal spinning of a slurry of titanium nitride (TiN) reinforcements and silicon matrix powders which will be fired and nitrided to produce a TiN outer-surface-reinforced silicon nitride (Si_3N_4) ring, and (2) infiltration of a graded porosity Si_3N_4 cylinder liner with Ti molten which will be subsequently carburized to form a titanium carbide (TiC) inner-surface-reinforced Si_3N_4 cylinder liner. Test specimens will be subjected to microstructural examinations and microhardness measurements. Sliding wear tests will be performed on mating specimens from the rings (TiN/Si_3N_4) and cylinders (TiC/Si_3N_4) in 800°C air, to enhance piston ring-on-cylinder liner contact. Coefficients of friction, wear rates, and lubrication mechanisms will be established. In Phase II, near-net shape fabrication of rings and cylinders will be studied through the use of controlled geometric dies.

Anticipated Results / Potential Commercial Applications as described by the awardee: Benefits afforded by this new class of CMC materials will include low-friction surfaces, high-wear resistance, and long-service lifetimes. Potential applications include seals, piston rings, cylinders liners, bearings, and gears for high-temperature diesel and turbine engines, bearing retainers/cages for oxidizer turbopumps, and components for chemical processing equipment in oxidizing environments.

80

Molded Titanium Carbide Bipolar Plates for High Voltage Battery and Fuel Power Sources--Giner, Inc., 14 Spring Street, Waltham, MA 02154-4497; (617) 899-7270
Dr. John A. Kosek, Principal Investigator
Dr. Anthony B. LaConti, Business Official
DOE Grant No. DE-FG02-93ER81610
Amount: $74,978

A lack of inexpensive, corrosion-resistant materials for bipolar plates is a major hindrance to commercialization of many advanced acidic electrochemical systems, where one of the electrodes operates at a high oxidizing potential. Under these conditions, graphite, a relatively low cost material, is unstable. Some stability improvements are possible through resin impregnation and high-temperature heat treatment. However, these processes result in significantly increased cost. In this project, bipolar plates made from corrosion-resistant titanium carbide (TiC) will be developed. In preliminary testing, such plates showed significantly better corrosion resistance at oxidizing conditions than graphite. Since the TiC plates will be manufactured using, a low-cost molding process, cost is expected to be less than resin-impregnated graphite plates. Furthermore, the Tic plates will have higher electrical conductivity than graphite plates. Phase I will develop procedures for molding bipolar plates with desirable physical, chemical, and electrochemical properties for use in acid-containing applications under oxidizing conditions. The effect of molding conditions on bipolar plate properties and the use of the plate in fuel cells will be investigated.

Anticipated Results / Potential Commercial Applications as described by the awardee: The advanced electrochemical systems, for which these bipolar plates are being developed, have a very large market potential. Advanced bipolar lead-acid batteries and proton-exchange membrane (PEM) fuel cells are being considered as power sources for electric vehicles. Regenerative PEM fuel cells would be useful in conjunction with solar cells, future power generation technologies, load-leveling or storage applications. Molded TiC bipolar plates could also find extensive applications in existing water electrolyzer technologies.

81

Low Temperature Deposition of Titanium Nitride--ISM Technologies, Inc, 9965 Carroll Canyon Road, San Diego, CA 92131; (619) 530-2332
Dr. Anthony J. Perry, Principal Investigator
Mr. Robert J. Stinner, Business Official
DOE Grant No. DE-FG03-93ER81577
Amount: $74,599

Titanium nitride (TiN) has been found to be an excellent coating for many wear applications. For example, a very high percentage of tool inserts are coated with titanium nitride. However, the temperature at which it is deposited, even for "low temperature" processes, such as cathodic arc deposition, is still too high for coatings on aluminum, polymers, many steels, and some other materials without reducing the strength of the base materials or creating other problems. The temperature at which titanium nitride is deposited by conventional physical vapor deposition processes, such as electron beam evaporation, sputtering, and cathodic arc deposition, must be high in order to prevent excessive stress build-up in the coating and to a achieve the desired micro-structure. A process for cathodic arc deposition has been developed whereby a pulsed, high voltage bias applied to the work piece allows deposition at near room temperature without excessive stress build-up and with superior adhesion. This project will extend this technology to the deposition of titanium nitride on aluminum, steel, and other materials that are not able to withstand the higher temperatures associated with conventional deposition technologies. Phase I will establish that TiN can be deposited at low temperatures using a pulsed, high voltage bias along with the conventional bias. The coatings should have low residual stress and good adhesion without loss of mechanical properties.

Anticipated Results / Potential Commercial Applications as described by the awardee: The ability to overcome the temperature limitation on titanium nitride and other similar coatings will lead to extended wear life of many components important to conserving energy. It may also allow aluminum to replace steel in many automobile parts that are subject to wear, reducing automobile weight and increasing fuel efficiency.

82

Room Temperature Photoluminescence of Germanium (Ge) Nanostructures by High Energy Implantation of Ge into a Buried Oxide of Silicon--Ibis Technology Corporation, 32A Cherry Hill Drive, Danvers, MA 01923; (508) 777-4247
Dr. L. P. Allen, Principal Investigator
Dr. G. Ryding, Business Official
DOE Grant No. DE-FG02-93ER81611
Amount: $74,927

The optical properties of nanometer sized indirect bandgap semiconductors is an area of great fundamental and practical interest. Demonstrations of room temperature yellow-orange Ge photoluminescence have made such quantum confinement effects of interest to both the commercial and military markets. A significant issue related to the practical application of Ge nanostructures is the ability to fabricate a uniform distribution of nanocrystalline precipitates in a silicon (Si) fabrication-ready matrix. This project will investigate a method of fabrication which incorporates the implantation of Ge^+ ions into a silicon-on-insulator (SOI) structure. The peak distribution of the Ge^+ implant is designed to match the buried oxide center position of the SOI wafers. In Phase I, a matrix of implant and anneal parameters is planned in order to obtain a thermodynamically predicted uniform layer of angstrom size Ge precipitates at a calculated depth. Characterization of precipitate presence and size will be performed, along with room temperature photoluminescence (PL) testing.

Anticipated Results / Potential Commercial Applications as described by the awardee: The results of this project will be directly applicable to high speed, high temperature optoelectronic integrated circuitry as well as to integration of high and low power circuitry on a Si fabrication-ready wafer. Commercial benefits will be demonstrated in the automotive, aerospace, communications, and general automotive original equipment manufacturing (OEM).

83

Nanoscale Processing for Ternary Semiconductors--Interphases Research, 722 Rushing Creek Place, Thousand Oaks, CA 91360; (805) 493-2257
Dr. Shalini Menezes, Principal Investigator
Mr. Leslie Affonso, Business Official
DOE Grant No.DE-FG03-93ER81576
Amount: $75,000

This project will develop an electrochemical technique to synthesize composition modulated ternary semiconductor alloys. Phase I is directed toward defining optimal conditions for the synthesis of novel superlattice structures based on I-VI-VII materials, particularly copper selenium iodide ($CuSe_3I$), an important component of a low cost n-$CuInSe_2$- based photovoltaic cell. The technique will be demonstrated by investigating the deposition of continuous-epitaxial and abrupt layered Cu-Se-I based superlattices. The reaction mechanisms and deposition parameters will be investigated by synthesizing and characterizing a variety of Cu-Se-I based superlattices. The information derived from this project will help to devise a generic electrochemical method to fabricate nanostructured materials.

Anticipated Results / Potential Commercial Applications as described by the awardee: The electrochemical approach offers cost, scale-up and environmental advantages. The I-VI-VII materials have potential non-linear-optical applications. In addition, $CuSe_3I$ plays a crucial role in a $CuInSe_2$-based solar cell. Atomic level structuring for this new class of materials will extend its applications to advanced opto-electronic devices.

84

Jet Vapor Deposition of Ultra-Thin Platinum Catalyst Loadings Directly on Polymer Ion-Exchange Membranes for Fuel Cell Applications--Jet Process Corporation, 25 Science Park, New Haven, CT 06511; (203) 786-5130
Dr. Bret L. Halpern, Principal Investigator
Mr. Jerome J. Schmidt, Business Official
DOE Grant No. DE-FG05-93ER81599
Amount: $75,000

Polymer Electrolyte Fuel Cell (PEFC) technology has great promise for the electric vehicle. However, state-of-the-art technology currently requires catalyst loadings of expensive noble metals such as platinum (Pt) at costs which hinder economic vehicular application of PEFCs. A novel Jet Vapor Deposition (JVD) process will be used to address this problem. JVD is capable of high rate, highly efficient deposition of metal particles. This project will deposit ultra-thin, nanometer-sized loadings of high surface area Pt electrocatalyst clusters directly on the surface of polymer electrolytes such as Nafion™ (DuPont). Phase I will test and evaluate samples to determine the catalytic effectiveness of these ultra-thin Pt deposits. It will also develop preliminary studies on process scale-up and production economics. Specialists in PEFC technology at Los Alamos National Laboratory and Ballard Power Systems will participate in Phase I.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful scale-up and optimization will lead to economic manufacture of fuel cells for vehicular transportation. JVD uses no toxic precursors and produces no toxic effluents, an important environmental benefit.

85

A Direct Thermal to Optical Energy Converter--New Material Concepts, 15 Guile Avenue, Tewksbury, MA 01876; (508) 851-2451
Mr. R. G. Roy, Principal Investigator
Mr. R. G. Roy, Business Official
DOE Grant No. DE-FG02-93ER81615
Amount: $74,918

This project will conduct crystal growth research on a single crystal rare earth oxide, which is expected to be a converter of thermal energy to a narrow wavelength emission in the near infrared. This crystal is expected to behave as a photonic band gap (PBG) material (a new class of materials). The concept of a PBG material was first explicitly described by Eli Yablonovitch (Phys. Rev. Lett. 58, (1987) 2059-2062). In Phase I, measurements will be made of the light emission from these crystals when they are heated to a temperature that can be achieved with a propane torch.

Anticipated Results / Potential Commercial Applications as described by the awardee: The PBG material is expected to be the basis for a thermally-pumped laser. If this material can be tailored to emit light at the wavelength at which silicon photovoltaic cells are most effective, a very efficient thermophotovoltaic (TPV) system should be easily achieved. This could be useful in providing electricity for decentralized applications, such as homes and shopping malls.

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Quantum Confinement Effects in Heteroepitaxial Silicon/Zinc Sulfide (Si/ZnS) Nanostructures Produced by Metallo-Organic Chemical Vapor Deposition--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. H. Paul Maruska, Principal Investigator
Mr. Patrick N. McDonnell, Business Official
DOE Grant No. DE-FG02-93ER81620
Amount: $74,788

Silicon multiquantum wells with lattice matched ZnS barriers will be grown on silicon substrates by organometallic chemical vapor deposition. Such silicon nanostructures are expected to exhibit the same quantum confinement effects that have already been reported for porous silicon, but now with a carefully controlled, planar crystal structure. Although silicon quantum wires produced by electrochemical etching show visible photoluminescence and electroluminescence, the fractal nature of those structures makes the preparation of reproducible devices unlikely. Because the Si/ZnS superlattices will be configured as waveguides, analogous to AlGaAs/GaAs quantum well structures, it is anticipated that silicon diode lasers operating at visible wavelengths may become possible. Visible photoluminescence has already been reported with Si/Si_3N_4 quantum well structures. Because ZnS can be made conducting, the capability to generate electroluminescence under relatively low electrical bias is expected. In Phase I, ZnS films will be prepared epitaxially by mixed oxide chemical vapor deposition (MOCVD) on perfectly cleaned silicon substrates, using a procedure recently developed at the University of Florida. Silicon films with thickness on order of 50Å will be deposited, using a photo-assisted deposition process and several silicon-based precursors. The goal of Phase I is to demonstrate photoluminescence from a single silicon quantum well. Phase II will proceed to investigate multiquantum wells, and configure the devices as junction diodes, to search for visible electroluminescence.

Anticipated Results / Potential Commercial Applications as described by the awardee: Silicon multiquantum well structures should yield commercial devices such as light-emitting diodes, laser diodes, tandem solar cells, and optical switches/modulators. They afford the promise of true wafer scale integration of all device functions in a single silicon wafer.

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Coated Micrograin Carbides for Wear Resistance--Ultramet, 12173 Montague Street, Pacoima, CA 91331; (818) 899-0236
Mr. Brian E. Williams, Principal Investigator
Mr. Craig N. Ward, Business Official
DOE Grant No. DE-FG03-93ER81584
Amount: $69,781

Micrograin carbides are small grain size (1-5 micron diameter) particles of tungsten carbide (WC) that have been "cemented" together with a predominantly cobalt matrix, using liquid phase sintering. They are an excellent material for carbide cutting tools and other wear- and/or corrosion-resistant parts, having better mechanical properties due to their finer grain size than typical carbide tools (20-50 microns). However, some of their potential advantage is lost because of the difficulty of handling such fine powders and mixing them with cobalt and nickel powders to form the blend which is then preformed and sintered. Problems that arise during handling and blending include increased impurity content, nonhomogeneous distribution of matrix powders, and WC-WC particle contact, all of which cause lowered mechanical properties in the finished part. The result is that higher cobalt contents must be incorporated to achieve the desired fracture toughness and transverse rupture strength, with a consequent decrease in tool hardness life. Phase I will demonstrate the feasibility of coating each individual WC grain with the proper thickness of cobalt matrix material so that, after consolidation, the problems resulting from powder blending (especially WC-WC particle contact and carbide formation) will be minimized or eliminated. This will not only improve mechanical properties and performance over conventional micrograin carbides, but also permit faster consolidation times with lower impurity contents and less deleterious interaction between the matrix and carbide. A large reduction in the amount of cobalt required is also expected.

Anticipated Results / Potential Commercial Applications as described by the awardee: This process should have early application to the market for carbide cutting tools. This technology can also help to improve process design and control in many areas of powder metallurgy, especially the emerging area of composites.

ADVANCED GEOPHYSICAL IMAGING IN GEOSCIENCES RESEARCH

88

Detection and Parameter Estimation from Electromagnetic Scattering Data in Offset/Reverse Vertical Seismic Profile Geometrics--A.J. Devaney Associates, Inc., 355 Boylston Street, Boston, MA 02116; (617) 424-9295
Dr. Alon Schatzberg, Principal Investigator
Dr. Anthony J. Devaney, Business Official
DOE Grant No. DE-FG02-93ER81604
Amount: $74,705

Detection, classification, and imaging of underground objects is of importance in geophysics and geochemistry of rock-fluid systems by providing information on geologic structure and providing a basis for interpretation of geochemical reactions in porous and fractured rock. A maximum likelihood multiparameter estimation approach to the problem will be used. An underground object to be imaged is parameterized so that the set of parameters is regarded as representative of the object itself. The Phase I goal is to estimate this set of parameters by computing their likelihood functions from a suite of offset/reverse vertical seismic profiling (VSP) electromagnetic scattering experiments and determining the values at which they peak. The parameters can be discrete such as presence/absence of a certain object from a class of possible objects (the detection/classification problem) or continuous such as object location, orientation, dimensions, and contrast. Phase I will investigate the use of newly developed diffraction tomographic maximum likelihood estimation techniques for detection and in an offset/reverse VSP geometry. The method is based on an exact scattering and propagation model that incorporates the electromagnetic and/or acoustic parameters of the surrounding ground and the polarization information in the scattering data. The method is ideally suited for accommodation of data from acoustic scattering experiments for refinement of the results.

Anticipated Results / Potential Commercial Applications as described by the awardee: A new approach to imaging underground phenomena from offset/reverse VSP scattering data will be developed and available for a host of applications such as geophysics and geochemistry of rock-fluid systems.

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Vertical Seismic Profiling: Spectrum Offset Inversion--Multi Spectrum Technologies, Inc., 914 Arizona Avenue, Suite 1, Santa Monica, CA 90401; (301) 576-0419
Dr. Alex Beylin, Principal Investigator
Dr. Simon Katz, Business Official
DOE Grant No. DE-FG03-93ER81580
Amount: $73,609

Many known oil and gas reservoirs have a heterogeneous and a multi-layered structure. Existing seismic methods aimed at analysis of their structure such as Amplitude-Versus-Offset analysis have limited resolution and are efficient only for the target zones of simple structure. It is important to develop a high resolution methodology for joint inversion of multi-offset, multi-source seismic data for the estimation of seismic parameters of a multi-layered reflecting target zone in the cases when the thicknesses of individual layers may be smaller than the wave length. This will lead to improved resolution of geologic structures and more efficient methods for detection of oil and gas reservoirs. Spectrum-Versus-Offset (SVO) methodology gives a high resolution imaging of the multi-layered target zone using multi-offset, multi-source inversion of frequency-offset functions. In this methodology, P and (or) S waves are used as input data. The list of estimated parameters includes P and S velocities, densities, and thicknesses of individual layers. This method includes the calculation of offset-frequency spectral functions free from an influence of the seismic source and upper part of the geologic section, forward modeling, interactive inversion of these functions, and high resolution imaging of the output parameters. The Phase I project will develop a methodology for the estimation and high resolution imaging of seismic parameters of a multi-layered target zone based on iterative constrained inversion of seismic data. In Phase II, SVO methodology will be expanded to multi-layered zones with horizontal inhomogeneities. SVO inversion of P and S waves will be developed.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful completion of this project will result in development of a technology for high resolution inversion of seismic waves reflected from multi-layered target zones and the imaging of seismic parameters of multi-layered zones. The methodology and experience acquired in Phase I will be used during Phase II for wider application of SVO methodology to the target zones of more complex structures, including zones with horizontal inhomogeneities, and demonstration of SVO methodology as a service and as a marketable software package.

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An Experimental Evaluation of Chaotic Waveforms for Crosswell Seismic Tomography–Radix Systems, Inc., 6 Taft Court, Rockville, MD 20850; (301) 309-6306
Dr. Jay Pulli, Principal Investigator
Mr. Mark R. Ciavardoni, Business Official
DOE Grant No. DE-FG05-93ER81603
Amount: $74,771

Seismic tomography provides the exploration industry with fundamental information on the structure and hydrocarbon potential of a subsurface. However, as exploration targets get smaller and more complex, tomographic imaging techniques become limited by the fundamental restriction of sampling and resolution. The use of higher-frequency sources provides little help, because attenuation limits the distances over which high-frequency seismic waves can propagate. Based on research with similar problems in the areas of underwater acoustics and radar, an experiment in crosswell tomographic imaging is planned using a new class of waveforms known as chaotic waveforms. A chaotic waveform represents the response of a nonlinear system that is aperiodic and depends on the initial conditions of the system. Unlike traditional frequency modulated (FM) sweeps which are narrowband at any given instance of time, a chaotic waveform is broadband over its entire duration, resulting in a sharper ambiguity function. Unlike random or pseudorandom noise, a chaotic waveform can be generated by a seismic source and tuned for a specific frequency band. Model studies indicate that the chaotic source waveform will improve the resulting seismic image. This experiment will compare the reconstructed tomographic images produced by the chaotic waveform, an FM slide, and an impulse. Wells selected for this experiment are separated by 330 ft. The test will cover the depth range of 2400 to 2700 ft, which includes Cretaceous limestones and shales from the Austin Chalk, Eagle Ford, and Buda formations.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned experiment will determine the feasibility of chaotic source waveforms for seismic imaging, and the extent to which they improve image resolution. If successful, the method will provide a low cost improvement in the methodology for pinpointing structural traps which may contain hydrocarbons, as well as the study of porous and fractured rock. Additional applications may include the search for shallow environmental hazards, and geothermal evaluation.

CHEMICAL SCIENCES RESEARCH

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On-Chip Infrared-Spectral Sensors by Superconducting Detector Arrays--Advanced Fuel Research, Inc., P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. David B. Fenner, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG0593ER81507
Amount: $74,717

Conventional methods of infrared (IR) spectroscopy for analysis of chemical species are limited to off-line instruments. The applications of a new, smart-detector design for IR spectral resolution is planned. This innovation accomplishes spectral resolution of IR directly on the detector chip assembly, and allows spectral analysis over a very wide wavelength range, limited only by the choice of optical window materials. This new spectral sensor is very small, compact, and rugged, especially if it is fabricated on a silicon wafer substrate. During previous research, the central concept was demonstrated: the sensor used a monolithic detector array fabricated with an interference-filter array; the detectors were photothermal bolometers of high-temperature superconducting films on silicon; and testing in a Fourier transform IR spectrometer verified that the device functioned as expected in model simulations. Phase I will adapt this design into a spectral sensor for chemical species analysis and monitoring, in a form suited to portable field installations and flexible programmability. Numerous specific expressions of this type of device can be envisioned, and will be the basis for much of the Phase II activity.

Anticipated Results / Potential Commercial Applications as described by the awardee: Smart IR detector devices, based on high-temperature superconductors, will provide both improved spectral chemical analysis for energy systems, and opportunities for novel kinds of commercial devices. These will be especially useful as compact and rugged monitors, with considerable flexibility to tailor their specific functionality, and hence with a wide market appeal.

92

Composite Plasma-Polymer Membranes--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. Walter C. Babcock, Principal Investigator
Dr. Walter C. Babcock, Business Official
DOE Grant No. DE-FG03-93ER81640
Amount: $73,921

The potential advantages of membrane processes for separations are well known. However, current membrane systems have captured only a small fraction of the potential market, primarily because they are made from polymers that are not durable enough for many applications, and they do not have sufficient selectivity for clean separations. Plasma-polymer membranes offer a solution to both problems. These membranes exhibit extraordinarily high selectivity, and they are so highly crosslinked that they are both chemically and thermally stable. The goal of Phase I is to develop a composite membrane consisting of a microporous support on which a thin, highly selective layer is deposited--all from plasma polymers. Such a membrane would overcome current selectivity and durability shortcomings of other membranes. Additionally, the process for making such membranes will prepare the way for making membranes directly from any of a wide range of organic or inorganic monomers and mixtures thereof, thereby extending the useful range of separation properties and overcoming the ever-increasing costs and the limitations on membrane-separation properties associated with using specialty polymers for membrane materials.

Anticipated Results / Potential Commercial Applications as described by the awardee: Development of these membranes would result in a new generation of membrane-based separation processes for applications such as hydrogen recovery in refineries, production of oxygen and nitrogen from air, purification of natural gas, and, perhaps most important, clean-up and recycle in the chemical process industry.

93

On-Line Micro-Sensors for Analytical Chemical Measurement--Ciencia, Inc., 111 Roberts Street, Suite C, East Hartford, CT 06108; (203) 528-9737
Dr. Salvador M. Fernandez, Principal Investigator
Mr. Arturo O. Pilar, Business Official
DOE Grant No. DE-FG05-93ER81597
Amount: $74,949

This Phase I project offers an innovative approach to microsensing which is expected to result in compact, rugged, versatile, highly sensitive sensor systems capable of sophisticated on-line spectral analysis in a broad class of chemical processes. These sensors would operate in real world factory environments and be capable of sensing micron-scale phenomena. They are true on-line sensors, not automated "grab sample" techniques. The key innovations include (1) the use of laser induced fluorescence to provide high sensitivity and high specificity in complex mixtures of similar compounds, (2) the use of acousto-optically tuned filters to replace the conventional scanning grating monochromators in current use in the laboratory to make rugged factory-compatible devices, (3) optical access that allows application to optically dense media, (4) imaging, fiber optic, and microscopic techniques to address very small sample sizes and to quantify inhomogeneity within a sample, and (5) high speed analysis techniques to permit real time operation. The planned sensors would be used in on-line real-time analytical chemical measurement for industrial process control.

Anticipated Results / Potential Commercial Applications as described by the awardee: Analytical chemical measurement on-line and in real time can reduce industrial production costs and improve product quality. Such measurements can be used for automated process control. Industries which will benefit from these innovations include the chemical, pharmaceutical, pulp and paper, food and beverage, petrochemical, and biomedical sectors.

94

Multiple Air Pollutant Emissions Removal by the Use of a Single Chemical Additive--Energy and Environmental Research Corporation, P.O. Box 189, Whitehouse, NJ 08888; (908) 534-5833
Dr. Vladimir Zamansky, Principal Investigator
Dr. Richard K. Lyon, Business Official
DOE Grant No. DE-FG05-93ER81538
Amount: $74,999

Air pollution control technologies for nitrogen oxide (NO_x) reduction are limited by the relatively inert nature of nitric oxide (NO). This difficulty can be overcome by oxidation of NO to much more reactive nitrogen dioxide (NO_2). Since flue gas desulfurization systems are required for sulfur dioxide (SO_2) removal after combustion of sulfur containing fuels, and since it has been proven that NO_2 can be removed efficiently in SO_2 scrubbers, the conversion of NO into NO_2 becomes a promising strategy for combined NO_x and sulfur oxide (SO_x) removal. A large number of wet scrubbers are already installed in stationary combustion sources or are planned for the near future. Therefore, a process that promotes NO removal simply through the injection of chemical additives into combustion gases could have a significant impact on air pollution control strategies. Phase I will develop a novel concept: gas phase multiple air pollutant emission removal by injection of a single chemical additive into combustion gases at high temperatures. Chemical kinetics calculations and experimental data available from the literature predict that an additive exists which, upon being injected into combustion gases at specific conditions, can efficiently convert all major gaseous air pollutants to NO_2, SO_2, and carbon dioxide (CO_2): unreactive NO, unburned carbon monoxide (CO), corrosive sulfur trioxide (SO_3), unburned hydrocarbons and dangerous organic byproducts. NO_2 and SO_2 can be efficiently scrubbed in a slightly modified calcium-based SO_2 scrubber. Phase I will provide a laboratory-scale feasibility demonstration of the critical steps of the process: the conversion of NO to NO_2, SO_3 to SO_2, and CO to CO_2 in the gas phase within reaction times, temperatures, and other conditions which are in the practical range for application in boilers and furnaces.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned technology, if combined with simultaneous SO_2/NO_2 scrubbing, makes it possible to organize a simple (by the use of a single additive), reliable, flexible, and extremely effective control of all major gaseous air pollutants emanating from combustion sources: NO_X, SO_X, CO, and organic compounds.

95

Solid Polymer Electrolyte Membranes for Olefin Separation--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025; (415) 328-2228
Dr. Ingo Pinnau, Principal Investigator
Ms. Elizabeth Weiss, Business Official
DOE Grant No. DE-FG03-93ER81579
Amount: $74,619

Separation of olefins from saturated hydrocarbons is an industrially important gas separation that is highly energy intensive using current technology. Membrane separation processes generally use much less energy than conventional processes such as distillation. Polymeric membranes have been applied successfully to a number of gas separations, including nitrogen production from air and hydrogen removal from refinery streams.

However, the selectivities and gas fluxes of polymeric membranes for olefin separation from saturated hydrocarbons are insufficient. Facilitated transport membranes often have higher selectivities than polymeric membranes. Facilitated transport membranes use reactions with a complexing agent incorporated into the membrane to selectively enhance the permeability of one of the components of a gas mixture. Two problems limit the application of facilitated transport membranes to industrial gas separation applications: membrane instability and low gas fluxes. The goal of this project is to produce chemically and mechanically stable facilitated transport membranes with high gas fluxes and high selectivities for the separation of olefins from saturated hydrocarbons. The selective membranes will consist of a polymer material that can dissolve the metal ion to be used as the gas complexing agent. This solid polymer electrolyte will be formed into a thin-film composite membrane. Phase I will demonstrate the feasibility of developing these polymer electrolyte composite membranes for the separation of olefins from saturated hydrocarbons. In contrast to previous facilitated transport membranes, the polymer electrolyte composite membranes are expected to be stable under high pressure operation and to exhibit substantially higher gas fluxes than conventional facilitated transport membranes.

Anticipated Results / Potential Commercial Applications as described by the awardee: Solid polymer electrolyte composite membranes could significantly reduce the energy consumption of many industrial gas separations, such as olefin separation from saturated hydrocarbons in the petroleum refining industry. The anticipated increase in selectivity and gas fluxes over state-of-the-art polymeric membranes and the improvement in stabililty and gas flux over facilitated transport membranes could make membrane systems competitive with conventional separation methods for this and similar applications.

96

Time Resolved Nitric Oxide Measurements in Combustion Exhausts--Physical Sciences, Inc., 20 New England Business Center, Andover, MA 01810; (508) 689-0003
Mr. Terence E. Parker, Principal Investigator
Mr. George E. Caledonia, Business Official
DOE Grant No. DE-FG02-93ER81617

Amount: $75,000

A research and development program is planned that would produce an instrument capable of providing real time measurements of nitric oxide (NO) concentrations in power plant or internal combustion engine exhausts. This instrument would be capable of monitoring transients in emission with a resolution of 10 ms or less. This approach utilizes an inexpensive, high-resolution instrument concept which is easily extendable to species other than NO. The motivation for this new capability is clear. Federal clean-air initiatives are pushing future emissions standards for nitrogen oxides (NO_x) to ever lower levels. A real time, non-extractive, NO monitor could be used as the sensor in a feedback control loop; information derived from this measurement system would allow diesel engine manufacturers to critically assess their engines' pollutant performance over their entire operating envelope. The key to the technical approach is to measure concentrations of NO with absorption diagnostics in the infrared and package the instrument in a fashion that facilitates its application to severe environments. In Phase I concentrations of NO will be derived from single line absorption measurements near 5.2 µm. This wavelength is chosen specifically to avoid spectroscopic features from other gases typical of combustion exhausts and be insensitive to typical loadings of particulates in these flows.

Anticipated Results / Potential Commercial Applications as described by the awardee: The outgrowth of this effort would be an instrument capable of monitoring transient emission behavior in combustion exhausts typical of either power plants or engine exhausts. An immediate market for the instrument is as a sensor in a urea-injection NO_x control system and as a specialized diagnostic tool for diesel engine manufacturers. In addition, the technology developed for this instrument could be applied to other gas emission scenarios and/or incorporated into other emission control equipment.

97

Improved Coated-Metal Hydrogen Extraction Membranes--REB Research and Consulting, 811 Oak Street, East Lansing, MI 48823; (517) 332-0243
Dr. Robert E. Buxbaum, Principal Investigator
Dr. Robert E. Buxbaum, Business Official
DOE Grant No. DE-FG02-93ER81625
Amount: $72,912

Coated refractory-metal membranes are suggested for hydrogen extraction from gas mixtures for hydrogen purification, for producing reformulated gasoline and for membrane-reactor use. Palladium-based membranes have been used for decades for hydrogen purification and membrane reactors because palladium combines high permeability, 100% selectivity, and good surface properties. Several refractory metals are higher in permeability, and are stronger and cheaper than palladium; they are not ordinarily used for these applications because poor surface properties reduce hydrogen transport. When these refractory metals are coated with palladium, however, the surface barriers are reduced. Membranes that result show hydrogen fluxes as high as 0.095 mol/m^2s for a driving pressure of 0.78 atm and a thickness of 0.25 mm, more than ten times greater than those available with palladium at 420°C, at lower cost and with the same 100% selectivity. Such membranes can be made thinner than 0.1 mm because of the strength of the refractory metals. Thinner membranes should show still higher hydrogen fluxes because flux increases as membrane thickness decreases. Membrane costs are estimated as $\$2500/m^2$ if the membranes are mass-produced. Current membranes are still laboratory prototypes, too thick and too small for most applications. In Phase I thinner-walled, larger-surface membranes will be made, and their hydrogen transport and durability measured. This will provide practical membranes for use in bench-scale industrial tests and will provide benchmark transport and cost data.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will move palladium-coated refractory-metal membranes toward commercialization by two steps: (1) producing the first large, thin-walled membranes that can be used in bench-scale tests of hydrogen extraction, and (2) demonstrating that these thin-walled membranes show high selectivity and high transport rates. This project aims at a membrane permeance of 0.0014 $mol/m^2Pa^{1/2}$ (where Pa is the pressure in pascals) and a cost of $\$5000/m^2$. There is considerable industrial interest in these membranes for hydrogen extraction in petroleum and petrochemical plants, and for membrane reactor applications.

98

Zeolite Membranes for Gas Separations--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033; (303) 422-7819
Dr. Zhiping Jiang, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-93ER81590
Amount: $75,000

Porous inorganic membranes can be used at high temperatures, and have high fluxes, mechanical strength, and chemical stability. However, commercially available inorganic membranes have large pores (>40Å), and a wide pore size distribution. While such membranes are ideally suited for removing high molecular weight components from a liquid stream (ultrafiltration), their ability to separate gases is limited. Because these membranes operate on Knudsen diffusion, their separation coefficients are far too low for use in gas separations. On the other hand, zeolite membranes have much smaller pores, and a well defined pore size distribution. Since they separate molecules by molecular sieving, they offer very high selectivity. Unfortunately, while the potential of zeolite membranes has long been recognized, there is still no suitable processing method by which either self-supported zeolite membranes or composite membranes (a zeolite film on a porous support) can be made. In Phase I, ZSM-5 zeolite films will be prepared on Al or Si substrates using a novel synthetic method, and then the chemical composition, morphology, thermal stability, and ion-exchange ability of the resulting films will be characterized. Phase II will further refine the preparation process, optimize the film characteristics, and measure the permeability factor of supported zeolite gas separation membranes.

Anticipated Results / Potential Commercial Applications as described by the awardee: The Phase I project should demonstrate a novel process for producing dense, continuous zeolite films on Si or Al. Large scale applications include membranes for use in gas separation and ultrafiltration. Additional applications include catalytic membrane reactors, solid-state batteries, chemical sensors, and other solid-state devices.

MATERIALS SCIENCES INSTRUMENTATION

99

An In-Situ Particle Sensor for Metal Forming Processes--Advanced Fuel Research, Inc., P.O. Box 380379, East Hartford, CT 06138-0379;
(203) 528-9806
Dr. Stuart Farquharson, Principal Investigator
Dr. David G. Hamblem, Business Official
DOE Grant No. DE-FG05-93ER81594
Amount: $74,957

Numerous processes are being developed for the manufacturing of advanced composites which incorporate ceramics, polymers, metals and/or metal alloys. The success of these manufacturing processes is critically dependent on the ability to both monitor and control the processing conditions. Of particular interest is the development of powdered metals as a source material for a variety of metal forming processes, such as plasma spray, sintering, and hot isostatic pressing. However, a lack of sensors is slowing the development of the powder technology. This project will develop and field test a metal powder smart-sensor which can be employed in the hot particle forming plume, in the following stream of formed particles, and as part of a sizing system to characterize collected particles. The technique employs Fourier Transform Infrared (FT-IR) spectroscopy to differentiate the scattering of various particle sizes. FT-IR Scattering (FT-IRS) spectroscopy relies on the wavelength dependence of light scattering rather than the angular dependence employed by other techniques. In addition, FT-IR emission spectroscopy in combination with FT-IRS offers a unique capability for particle temperature measurements in the plume. Because of the FT-IR's capabilities, a single spectrometer will be able to monitor particle size distributions and temperatures in a process stream, and issue process control commands. In Phase I an FT-IR instrument for in-situ particle analysis of the plume of a metal powder facility (MPF) will be developed and field tested. The instrument development would include coupling of two detectors for long and short wavelength measurements, the development of optics to couple the instrument to the MPF, the development of a calibration system, and fast data acquisition and analysis algorithms applicable to high-rate metal forming processes. Field testing will occur over a one to two week period in the fifth month of the program.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned instrument will measure particle size, particle temperatures, gas compositions, and gas temperatures in hot, multi-phase media. The instrument is rugged, user friendly, portable, and relatively inexpensive. The applications include metal particle production, plasma spray forming, coal combustion, municipal or hazardous waste disposal, stack gas monitoring, ambient air monitoring, furnaces, lime kilns, pulp and paper manufacturing, and semiconductor device manufacturing.

100

A High Count Rate Two-Dimensional Neutron Detector--Advanced Optical Technologies, Inc., 628 Hebron Avenue, Glastonbury Corporate Center, Building 2, Glastonbury, CT 06033-2495; (203) 657-2668
Dr. Yong-Sheng Chao, Principal Investigator
Mrs. Feng Liu, Business Official
DOE Grant No. DE-FG05-93ER81595
Amount: $74,639

Most major neutron facilities operating in the U.S. were developed two or three decades ago. To meet the new challenges for materials and biological research in the future, a new generation of neutron facilities with much higher flux and with compatible instrumentation is being considered. The current technology of neutron detection (gas-filled, proportional, position-sensitive chambers) could not meet the needs in an advanced neutron source environment because of the inherently limited maximum count rate, limited spatial resolution, and limited detection efficiency, especially for neutrons with shorter wavelength. To meet the needs for neutron scattering and neutron diffraction experiments at higher neutron fluxes, this Phase I project will study the development of a large format, integrated, amorphous silicon, photodiode array coupled with an efficient scintillator. The novel two-dimensional neutron detector is expected to be able to improve the maximum count rate from the current 10^5-10^6/second given by a gas-filled chamber to 10^8-10^9/second, resulting in significantly improved productivity and data throughput. Spatial resolution is expected to be enhanced from the current 5 mm level to a submillimeter level. Parallax error produced by gas-filled detectors will be eliminated, and at the same time detection efficiency for shorter wavelength (down to 0.5Å) neutrons would also be substantially improved. Phase I should demonstrate feasibility of the planned approach, and Phase II would provide a prototype two-dimensional neutron detector.

Anticipated Results / Potential Commercial Applications as described by the awardee: Upon successful completion of Phase I and Phase II, a new neutron detection technology for advanced high flux neutron sources will be available. When compared to current capabilities, all major performance parameters, as well as research productivity would be substantially enhanced.

101

A Wavelength Dispersive Spectrometer for Analytical Electron Microscopy--Advanced Research and Applications Corporation, 425 Lakeside Drive, Sunnyvale, CA 94086; (408) 733-7780
Mr. Edward D. Franco, Principal Investigator
Mr. Ed LeBaker, Business Official
DOE Grant No. DE-FG03-93ER81566
Amount: $75,000

The development of a novel non-scanning wavelength dispersive spectrometer (WDS) for analytical electron microscopy (AEM)is the objective of this project. This spectrometer is designed to provide sufficient energy resolution over broad regions of the soft x-ray spectral region (from 100 to 2000 eV) to allow the observation of the K-emissions of the light elements (those with atomic numbers less than 10) as well as the L, M, and N emissions of the heavy elements. The large solid angle of this spectrometer and its non-scanning geometry decrease the analysis time compared to conventional WDS instruments while offering at least a fourfold increase in spectral resolving power compared to energy dispersive detectors currently offered in the AEM marketplace. The Phase I objective is to experimentally evaluate the performance of a prototype spectrometer in terms of lower limits of detection in the energy range from 150 to 300 eV in a re-entrant AEM environment. This objective will be accomplished by the fabrication of a single channel prototype of the spectrometer and the measurement of the signal and background levels in a modern AEM.

Anticipated Results / Potential Commercial Applications as described by the awardee: This spectrometer is an accessory to AEM, scanning electron microscopy, and microprobe analytical instruments and is intended for light element analysis as well as the study of surface processes. The analytical technique will allow the refinement of existing material production processes as well as the development of new classes of materials engineered for a particular set of properties. For example, this new capability will contribute significantly to understanding how to improve the efficiency of catalysts, the resistance of materials to corrosion and temperature, the development of specialized metallurgical alloys used in aerospace, and the development of high density semiconductor integrated circuits.

102

Development of a High Spatial Resolution Neutron Detector--BioTraces, Inc., 7986 Lakecrest Drive, Greenbelt, MD 20770; (301) 345-3279
Dr. A. K. Drukier, Principal Investigator
Dr. A. K. Drukier, Business Official
DOE Grant No. DE-FG05-93ER81602
Amount: $75,000

Neutron scattering studies have been usually carried out using single detectors. In the last few years, the use of spatially resolving detectors has resulted in better statistical accuracy with substantially reduced data collections times. Although, the commonly used neutron detector array consisting of mulitwire He-3 camera is capable of excellent photonic background rejection, its use is severely limited due to low spatial resolution and count rate limitations. To overcome these difficulties, development of a new class of high spatial resolution neutron detectors based upon superconducting energy-sensitive structures is planned. A detector with a few square centimeter area, excellent spatial resolution, and high detection efficiency will be developed. The crucial component of this detector will be a large array (2048 x 2048) of superconducting sensors deposited on the surface of a neutron absorber (e.g. boron, boron nitride, or lithium hydride) which will act as a neutron to alpha particle "converter". Such a detector can attain a spatial resolution of a few tens of microns with a reasonable number (≤256) of readout channels. In Phase I, a prototype detector on the surface of a boron nitrite substrate will be fabricated. Furthermore, a multichannel electronic readout system will be developed to enable quantitative measurements of the spatial resolution and quantum detection efficiency.

Anticipated Results / Potential Commercial Applications as described by the awardee: Radiation-hard, high spatial resolution visible/ultraviolet (UV)/X-ray detectors have a large commercial potential. The proposed effort may also indirectly facilitate development of γ-ray detectors for Nuclear Medicine applications.

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A High Resolution Scintillator-Based Neutron Detector--Nanoptics, Inc., 3014 NE 21st Way, Gainesville, FL 32609; (904) 378-6620
Dr. Won Y. Choi, Principal Investigator
Dr. James K. Walker, Business Official
DOE Grant No. DE-FG05-93ER81600
Amount: $75,000

A novel technology for a scintillator-based neutron converter plate which will have high thermal neutron detection efficiency (~90%) and inherently high spatial resolution is planned. The neutron converter plate will be made using scintillating plastic micro-fibers with enriched lithium (^{6}Li) incorporation. This neutron converter overcomes the fundamental problems associated with screen phosphors and will be a superior alternative. The detector can be used either for a time-integrating imaging mode or for a conventional time-resolved position sensitive detector mode. Phase I will develop and test the novel neutron converter plate. Measurements will include neutron detection efficiency, scintillation efficiency, absorption/emission spectrum, and decay time of the scintillator. The results of Phase I will demonstrate the effectiveness of the converter plate compared with those obtained from standard screen phosphors. In Phase II, a complete real-time thermal neutron imaging system using the neutron converter will be built and applied to various thermal neutron imaging applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: Several National Laboratories which have neutron scattering experiment facilities will benefit from this new kind of scintillator. Another potential commercial application is industrial neutron radiography for non-destruction examination applications. These applications include quality assurance of major components of jet engines, visualization of flow in steel pipes, and various material inspections including nuclear fuels.

HIGH PERFORMANCE COMPUTING RESEARCH

104

Parallel Wavelet Methods for Computational Fluid Dynamics--Aware, Inc., One Memorial Drive, Cambridge, MA 02142; (617) 577-1700
Dr. John Weiss, Principal Investigator
Dr. Howard L. Resnikoff, Business Official
DOE Grant No. DE-FG02-93ER81523
Amount: $74,088

Numerical methods have been developed for solving nonlinear partial differential equations, using the family of compactly supported wavelet functions that are orthogonal. Being both compactly supported and orthogonal, the wavelets combine the advantages of finite element, spline, and Fourier spectral methods. To test the feasibility of the wavelet methods, phenomena that exhibit singular behavior were examined. These include shocks (e.g. Burgers equation, the gas dynamics/compressible Navier-Stokes equations) and turbulence (incompressible Navier-Stokes equations). The various technical problems that occur in the practical use of wavelets have been solved, i.e., exact evaluation of functionals and boundary value problems. Wavelet based methods could provide a major advance in the field of computational fluid dynamics. It is expected that wavelets will be particularly useful in resolving phenomena related to turbulence and shock dynamics and to interface discontinuities, i.e., electromagnetic and acoustic, direct, and inverse problems. Phase I will develop two-dimensional, parallel versions of the Wavelet-Galerkin algorithm for the Euler and Navier-Stokes equations. These wavelet methods (Wavelet and Capacitance Matrix methods) are driven by the periodic solvers for the Euler and Navier-Stokes equations. On serial machines current wavelet methods can be faster than the fast Fourier transform based spectral methods. The computational bottleneck is in the evaluation of the nonlinear terms (90% of central processing unit time.) However, the wavelet evaluations, because of local support of the wavelet basis, are perfectly parallel. Therefore, it will be extremely efficient to develop these methods on, for instance, the Intel Touchstone platform.

Anticipated Results / Potential Commercial Applications as described by the awardee: The development of wavelet-based software products for the integration of fluid mechanics with the computer aided design process is anticipated. This requires methods that are flexible, stable, accurate, and fast. However, for use in engineering applications where the interaction of design and fluid behavior is critical, far greater speed will be required. The computational bottleneck for Navier-Stokes equations is in the evaluation of the nonlinearities. Fortunately, the compact support of the wavelet basis allows a completely parallel implementation of the calculation.

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A Rapid Calculation of the Coulomb Field in Large Molecules--Q-Chem, Inc., 7520 Graymore Road, Pittsburgh, PA 15221; (412) 268-1056
Dr. Benny Johnson., Principal Investigator
Dr. Carlos A. Gonzalez, Business Official
DOE Grant No. DE-FG05-93ER81643
Amount: $75,000

Recently there has been a rapidly growing interest in Density Functional Theory (DFT) as a general procedure for predicting physical properties of molecules. This is relatively inexpensive compared to traditional correlated methods. For the largest molecular systems whose study is feasible by the current DFT program (several hundred atoms), the treatment of the Coulomb interactions, with its quadratic cost in system size, is computationally dominant. In order to be able to perform calculations on truly large molecules, a breakthrough in the scaling of the Coulomb contribution is required. In Phase I an alternate approach to the Coulomb problem which will reduce the intrinsic order of the computational cost dependence on system size will be investigated. During Phase I an initial implementation of this method will be developed and tested, and, since the approach is particularly well-suited for massively parallel architectures, subsequent extension to such platforms during Phase II is not expected to be difficult.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned research will allow highly accurate density functional calculations to be carried out on much larger systems than is possible with current techniques and programs. This will be of considerable value to researchers in computational quantum chemistry and physics at universities as well as industrial and government facilities.

TECHNOLOGY FOR THE SUPERCONDUCTING SUPER COLLIDER

106

A Simple, Superconducting Elementary-Charge Polarity Detector--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523; (914) 592-1190
Dr. Elie Track, Principal Investigator
Dr. Hollis L. Caswell, Business Official
DOE Grant No. DE-FG02-93ER81542
Amount: $74,628

A novel detector capable of identifying the electric charge of a single relativistic elementary particle is planned. The detector measures the magnetic field generated by the particle by allowing this magnetic field to induce a current in a superconducting loop. The existence and sign of the loop current, and hence the polarity of the electric charge, are then identified using a superconducting comparator. The high sensitivity required to enable such a measurement is achieved by the use of an array of loops configured as a detecting antenna, and resulting in a current pulse which can be detected with the demonstrated ultrahigh sensitivity of superconducting circuits. The complete detector can be fabricated monolithically on a single substrate, and allows dense packing of a large array. This detector, when used in combination with energy measuring calorimeters, can replace the spatial tracking detectors currently used in high energy accelerators to determine the momentum of particles (and hence their charge polarity). These tracking detectors increase significantly in size, weight, and cost, as the energy of the experiments increases, and eventually become unable to resolve the charge of the particles. The planned detector will result in significant savings in size, cost, and weight. Phase I will demonstrate the feasibility of the principle by showing the superconducting circuit capable of resolving the current pulse resulting from the magnetic detection of a single particle. In Phase II, the circuit will be combined with the detecting antenna and demonstrated in an actual accelerator.

Anticipated Results / Potential Commercial Applications as described by the awardee: The detector should enable significant savings in cost and improvement in performance in high energy accelerators, and in the Superconducting Super Collider in particular. The high sensitivity detector development will enable improvements in magnetic detectors used in medical diagnostics and scientific instrumentation.

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Fabrication of a Superconducting Super Collider Dipole Magnet Bore Tube Liner from Copper-Niobium Nanocomposite Produced by Mechanical Alloying--Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545; (508) 842-0174
Mr. Charles Renaud, Principal Investigator
Ms. Elaine Drew, Business Official
DOE Grant No. DE-FG02-93ER81622
Amount: $74,984

A need exists at the Superconducting Super Collider Laboratory (SSCL) for a high strength, moderate conductivity copper based alloy or composite for possible application as a bore tube liner for the dipole magnets. The effectiveness of the tube in this application is a function of the material's resistivity and the wall thickness of the tube. This results in a narrow range of acceptable resistivities. If the material is too conductive the wall thickness must be reduced to the point where the wall is so thin that it may not survive the forces generated during a magnet quench. Most commercially available copper alloys are either too resistive or not resistive enough at the required strength levels. However, copper-niobium (CuNb) nanocomposite does possess the desired strength/resistivity combination. While the highest strengths have been reported in wire drawn composites, this form is inappropriate for a number of potential applications such as the above bore tube liner because of the very large cold work strains that must be applied to the material to develop its high strength. A more flexible method of processing which will allow material to be produced in more usable shapes while retaining, or exceeding, the strength observed in wire drawn materials is desired. Mechanical alloying will be employed in an effort to develop the required properties in the desired product form. This should produce a product possessing the required properties in the as-extruded condition eliminating the need for extensive cold work strain. Also, because of their nanometer scale microstructure the niobium dispersoids will resist coarsening at elevated temperatures so that the strength of the product will be negligibly effected by high temperature operations such as brazing. The objective of Phase I is to demonstrate that CuNb nanocomposite can be fabricated by mechanical alloying techniques and that its nanocrystalline microstructure will impart anomalously high strengths in the as-extruded condition. An evaluation of the composite's suitability for SSC bore tube liner applications will be conducted. The Phase II objective is to resolve any remaining technical issues and scale-up the process to produce bore tube liner sections for magnet quench testing at SSCL.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated results of the Phase I research will be the development of a method by which the excellent mechanical and electrical properties produced in highly deformed CuNb nanocomposites can be developed in pieces of large cross section and pieces of limited cold work strain. This work should result in a viable material for application as the collider beam bore tube liner in the SSC. Elimination of rebundled billets and their associated wire drawing, cleaning, wire straightening, and subelement cutting operations will significantly reduce manufacturing costs and greatly simplify billet design. Commercial applications encompass all areas in which high strength, high conductivity materials are presently used.

TECHNOLOGY AND INSTRUMENTATION FOR HIGH ENERGY ACCELERATORS

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A High-Performance Cryogenic Heat Exchanger--
Creare, Inc., P.O. Box 71, Hanover, NH 03755; (603) 643-3800
Dr. Javier A. Valenzuela, Principal Investigator
Mr. Robert Hickin, Business Official
DOE Grant No. DE-FG02-93ER81537
Amount: $74,988

Recuperative heat exchangers are key components in refrigeration systems used to cool superconducting devices in high energy physics research. Present plate-fin heat exchangers have effectiveness of around 0.97 and pressure drops of several percent of the stream pressure. Approximately half the losses in a cryogenic refrigerator are the results of ineffectiveness and pressure drop in the heat exchangers. Large vacuum enclosures and vacuum pumping systems are required to house the heat exchangers. This project will develop a high performance cryogenic heat exchanger which has the potential for decreasing heat exchanger losses by a factor of 3 and decreasing the heat exchanger size by a factor of 10 or more. Performance gains are achieved through a novel core configuration which minimizes axial conduction losses in the metal and allows a very compact design. Phase I will evaluate the feasibility of the proposed heat exchanger concept by performing a thermal design of the heat exchanger and demonstrating the key fabrication steps. In Phase II a full scale prototype heat exchanger will be built and tested.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned heat exchanger will increase the cooling capacity or reduce the input power of cryogenic refrigerators by as much as 30 percent. This recuperative heat exchanger would also have widespread application in the process and energy industries.

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Reliable Centrifugal Machines for Helium Circulation in Cryogenic Refrigerators--Creare, Inc., P.O. Box 71, Hanover, NH 03755; (603) 643-3800
Dr. Herbert Sixsmith, Principal Investigator
Dr. Paul H. Rothe, Business Official
DOE Grant No. DE-FG02-93ER81629
Amount: $71,906

This Phase I project addresses the need for robust, contamination-free circulators to distribute liquid or supercritical helium through superconducting magnets. An advanced centrifugal machine suitable for liquid or gas circulation at cryogenic temperatures will be developed. The machine incorporates two innovative features that provide for high efficiency and reliable operation in the presence of significant pressure transients. This development will demonstrate enabling technology that can be scaled to a variety of machines over a broad range of pumping and compressing capacities. The planned concept combines a unique, highly damped pressurized gas bearing system to accommodate severe pressure loads, and a solid rotor motor to increase the range of acceptable operating speeds, thereby enhancing performance. This machine represents a significant improvement over self acting gas bearing systems in terms of load capacity, and is significantly easier to control than electromagnetic shaft support systems.

Anticipated Results / Potential Commercial Applications as described by the awardee: The result of this development should be a robust centrifugal machine that has applications in low temperature superconducting magnet systems, in the chemical process industry, and in experimental high temperature helium circulating systems where contamination-free operation is critical.

110

A Microwave Power Combiner for a Cluster Klystron--Duly Research, Inc., 1912 MacArthur Street, Rancho Palos Verdes, CA 90732; (310) 548-7123
Dr. David U. L. Yu, Principal Investigator
Dr. David U. L. Yu, Business Official
DOE Grant No. DE-FG03-93ER81573
Amount: $74,766

This project will investigate methods of extracting microwave power from a cluster klystron by combining several low-current, medium-power klystrons to produce high peak power with very high efficiency. A cluster klystron in combination with a pulse compression system can be used as a radiofrequency power source for future linear colliders. Phase I will consist of feasibility and design studies of multi-gap coupled output cavities and cylindrical combiner waveguides capable of producing 150-MW, microsecond long pulses at 11.4 GHz. Several schemes of traveling wave output structures and waveguide coupled combiners operating in the circular TE01 or TM01 mode will be considered. Concepts of TM01 to TE01 mode converters will also be studied. This will facilitate interface with a SLED-II type pulse compression system which operates in the circular TE01 mode. The approach of using traveling wave structures with coaxial or rectangular output waveguides to extract power from several low-purveyance sources, which are phase synchronized and then coupled by irises to a combiner to produce high power, promises to be a cost effective method. Computer methods developed in this project will be applicable to the design and analysis of a wide range of microwave components.

Anticipated Results / Potential Commercial Applications as described by the awardee: The microwave power extractor/combiner can be used in a multiple-beam klystron as an efficient power source to meet the requirements of future linear colliders. The combiner is a key component of the cluster klystron. The cluster klystron can also be used to power a compact accelerator for industrial, medical and research applications. Long-pulse, high-power microwaves also have potential uses in defense and communications.

111

An Efficient 10-20 Gigahertz High-Power Microwave Amplifier--FM Technologies, Inc. 10529-B Braddock Road, Fairfax, VA 22032; (703) 425-5111
Dr. Frederick M. Mako, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG05-93ER81560
Amount: $74,992

This project involves the analysis of a high harmonic, high efficiency microwave generator that appears to be suitable for applications such as a driver for the next generation of linear colliders. The concept employs a rotating "spiraling" beam to excite and amplify circularly polarized microwave radiation in an interaction output waveguide. Modulation of a linear, high power, small diameter beam is obtained in a deflection system composed of a set of rotating mode resonators working at the drive frequency. An output waveguide is employed to efficiently extract energy from the rotating beam at a frequency that is a multiple integer of the drive frequency. Initial numerical analysis and self-consistent computer calculations performed on a 500 kV, 150 A beam, with a 2 GHz drive frequency, give indication of highly efficient capabilities (η~80%) for the generation of 50-70 megawatt 10 GHz microwave output radiation. In Phase I, detailed analysis and multi-particle simulation of this concept will be conducted in order to characterize the power, efficiency, gain, and other key parameters.

Anticipated Results / Potential Commercial Applications as described by the awardee: If successful, this generator should provide coherent, efficient microwave power for several applications that require 10-20 GHz high power microwaves at high efficiency. Of particular interest are particle accelerator drivers, such as future linear colliders. The planned device should be smaller and lower in cost than klystrons.

112

A 17 Gigahertz High-Gradient Accelerator Structure for a Compact 30 MeV, Picosecond Bunch Electron Source--Haimson Research Corporation, 4151 Middlefield Road, Palo Alto, CA 94303-4793; (415) 493-5012
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-93ER81487
Amount: $74,919

Ongoing studies of electron accelerator linear colliders and results presented at recent international workshops continue to support earlier contentions that the most favorable choice of linac frequency is in the range of 10 to 20 GHz with growing interest in the upper end of this band, and in increasing the number of bunches per pulse. Although considerable interest exists in 17 GHz linear collider concepts, and 17 GHz high peak power radio frequency (RF) generator research and development activities are already in progress at the Massachusetts Institute of Technology (MIT) and in industry, there are no accelerator waveguide structures presently available to support 17 GHz high gradient accelerator research. (Microwave accelerator structure development for linear colliders is at 14 GHz in Russia, and at 11.4 GHz in the USA and Japan.) Phase I studies the microwave and beam optics parameters of a 17 GHz traveling wave (TW) accelerator structure designed for 30 MeV, 5 degree bunch (0.8 ps) operation, using a high voltage electron injector and an input peak RF power of 20 MW. The accelerator waveguide is being designed as a high gradient (50 MeV/m), nonuniform impedance structure capable of operating in both the steady state and stored energy regimes, and having an RF filling time of approximately 70 ns. It is a further objective of the Phase I effort to prepare an overall facility layout drawing indicating the intended method of integrating the proposed 17 GHz accelerator centerline with an existing high power 1 µs pulsed modulator at the MIT Plasma Fusion Center. In Phase II, the 17 GHz TW accelerator structure and its diagnostic equipment shall be fabricated and installed in an existing radiation shielded facility, and high power tests shall be conducted to evaluate the performance of the structure.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that the Phase I and Phase II efforts will result in the design, fabrication, and high power testing of a 17 GHz linear accelerator system that will form the prototype of a compact, 30 MeV electron source suitable for advanced accelerator applications, and will provide a unique test facility to assist in evaluating 17 GHz linear collider technology.

113

Thermo-Mechanical Processing of Niobium Titanium Based Superconductors--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Hem C. Kanithi, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-93ER81598
Amount: $75,000

Ductile niobium titanium (NbTi) alloy continues to be the choice material for most of the large scale superconductivity devices. The present processing technology for NbTi superconductors involves working the composite in several stages with intermediate heat treatments to successively increase the amount of alpha titanium precipitate. The effect of the complex set of possible heat treatment conditions is reasonably well understood. It is generally true that a high current density (J_c) can be achieved by increasing the number and length of heat treatments. However, strain space available for multifilament composites after the last hot extrusion is small, limiting the number of heat treatments. Furthermore, the increased number of heat treatments adds processing cost and time. It has also been observed through microscopy that the cold-work/heat treatment cycles result in a non-uniform deformation of NbTi grain structure which in turn leads to uneven precipitation of alpha phase within the NbTi beta grain structure. This project will investigate a processing concept that is novel to the NbTi technology. Based on thermo-mechanical processing (TMP), it has the potential of achieving a more uniform distribution of precipitates in higher volumes and, therefore, higher J_c than the conventional cold-work/heat treatments are capable of. The Phase I project will investigate the feasibility of the TMP approach using rudimentary monofilament and multifilamentary composites, and will evaluate the resultant microstructure and superconducting properties. If proven successful the TMP will replace most if not all in-process long-term heat treatments and will offer an economical and high rate production technology.

Anticipated Results / Potential Commercial Applications as described by the awardee: The primary result of this research is the development of an economical high-rate production process for NbTi superconductors. By eliminating or greatly reducing the long-term heat treatments, the new method can significantly cut down the total processing time. With enhanced flux pinning a $J_c(5T)$ above 3200 A/mm^2 is possible in practical multifilament conductors. Expected applications include high energy physics accelerators, superconducting magnetic energy storage, special purpose high field magnets in the proposed Superconducting Super Collider ring, and magnetically levitated transportation.

114

A High Current, High Brightness Ferroelectric Electron Source for Advanced Accelerator Applications--Integrated Applied Physics, Inc., 261 North San Gabriel Boulevard, P. O. Box 70166, Pasadena, CA 91117-7166; (818) 449-0039
Dr. George Kirkman, Principal Investigator
Ms. Roberta Gunderson, Business Official
DOE Grant No. DE-FG03-93ER81575
Amount: $74,985

High current, high brightness electron beam sources are required for advanced accelerator applications which include electron guns for high power microwave sources, flash x-ray sources, and injectors for high gradient accelerators. Present electron beam sources such as thermionic cathodes, field emission cathodes, and photocathodes, are either inadequate in performance (such as in beam quality, current density, or current uniformity) or require ultrahigh vacuum systems or expensive and complex laser systems. In this project a high current, high brightness cathode based on emission from ferroelectric materials will be developed. Ferroelectric cathodes operate at room temperature using spontaneously polarized materials such as lead titanate-zirconate. Previous research has demonstrated that these cathodes produce high current density, high quality electron beams. Electron emission occurs upon polarization change induced by a fast (~20 kV/cm) pulse applied to the material. Previous research has indicated high brightness ($>10^{11}$ A/m^2rad^2) performance operating at pressures as high as 10^{-8} Torr. Room temperature emission of electrons combined with high current capability and high current density (possibly exceeding 100 A/cm^2) may allow beams with brightness $>10^{12}$ A/m^2rad^2, which is superior to beams from photocathodes. During Phase I, the design, fabrication, and testing of the ferroelectric cathodes capable of producing high brightness beams will be carried out. During Phase II, a prototype high voltage electron gun for commercial applications will be built and tested at high repetition rates. The device will be developed for industrial and scientific applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: The proposed research should lead to a novel electron beam source capable of producing high quality electron beams of high current density. This source could be commercialized as an inexpensive electron gun for applications in high power microwave generation, advanced accelerators, x-ray generators, switches, materials processing systems, and other applications.

115

A Mode-Locked Pulse Pre-Amplifier for Photocathode Illumination--Lightwave Electronics Corporation, 1161 San Antonio Road, Mountain View, CA 94043; (415) 962-0755
Mr. Martin Gifford, Principal Investigator
Dr. Richard W. Wallace, Business Official
DOE Grant No. DE-FG03-93ER81489
Amount: $74,983

Mode-locked laser pulses are required for generating bursts of electrons from photocathodes. These electrons are used to seed linear accelerators and free electron lasers. The photocathodes are typically illuminated with 10 to 100 µJ per pulse of energy in the ultraviolet. Diode-pumped Nd:YLF and Nd:YAG mode-locked oscillators have recently been developed with low timing jitter and repetition rates around 100 MHz that are the preferred front end for the photocathode illumination systems. The application requires selecting a 1 to 10 µs long section of the mode-locked pulse train for amplification by 40 to 60 dB; this is currently achieved with a Pockels cell switching technology and a two or three stage lamp-pumped amplifier chain. This Phase I effort plans a diode-pumped multipass pre-amplifier to increase pulse energies from a diode-pumped mode-locked oscillator by 20 to 30 dB, eliminating the need for one or two of the lamp-pumped stages. It also plans a pulse selection technique using an acousto-optic Bragg modulator. The diode-pumped pre-amplifier would generate pulse trains with energies up to about one µJ per pulse, with better stability and reliability than the lamp-pumped amplifier stage. The goals of this project are to characterize the diode-pumped amplifier, demonstrate pulse-train macropulse selection using an acousto-optic Bragg modulator, and to investigate amplifier effects on pulsewidth such as gain narrowing and gain saturation.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase I will characterize a diode-pumped pre-amplifier for use with a diode-pumped mode-locked pulse train. Phase II work would include developing a diode-pumped power amplifier that will lead to an all-solid-state laser for photocathode illuminators. The system would be more compact and reliable than flashlamp-pumped lasers. The integrated oscillator-amplifier combination will have commercial sales for biology, chemistry, and physics applications.

116

Development of a 100 Megawatt X-Band Relativistic Klystron Amplifier--MDS Company, 1955 Mountain Boulevard, Suite 101, Oakland, CA 94611; (510) 339-0957
Dr. Patrick Ferguson, Principal Investigator
Dr. Patrick Ferguson, Business Official
DOE Grant No. DE-FG03-93ER81491
Amount: $75,000

Future high gradient linear particle colliders operating at X-band with acceleration gradients exceeding 100 MeV/m require radio frequency (RF) sources capable of generating high peak power at high efficiency. To meet this need, analysis, computer simulation, and RF testing will be used to design a 100 MW relativistic klystron operating at 11.424 GHz with 120 Hz pulse repetition rate and a minimum pulse width of 1.0 microsecond. The analysis, design and simulation will be based on conventional klystron theory. In Phase I, a low perveance electron gun capable of generating a solid electron beam from a thermionic cathode operating in ultra high vacuum will be designed as well as an electromagnetic-electron beam interaction circuit capable of producing 100 MW with a minimum saturated gain of 50 dB and a minimum efficiency of 50%. A multiple cavity output circuit capable of efficiently extracting the fundamental RF power from the electron beam will be designed and analyzed for possible RF electric field breakdown. High thermal capability, long life and robust construction will be emphasized. All cavities including the multi-cavity output circuit and an output waveguide assembly with multiple ceramic windows will be designed, fabricated and RF tested.

In Phase II, the mechanical design, fabrication and RF testing of the various subassemblies will be completed and this 100 MW X-band relativistic klystron amplifier will be assembled and tested.

Anticipated Results / Potential Commercial Applications as described by the awardee: Anticipated results are the successful design of a 100 MW X-band high duty klystron. This klystron could be a high power source for future linear colliders and for high gradient electron accelerators for commercial applications. With additional gain cavities, this klystron can be broadbanded for military applications.

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Magnetron Arrays for Linear Colliders--Mission Research Corporation, 735 State Street, P.O. Drawer 719, Santa Barbara, CA 93102-0719; (805) 963-8761
Dr. Richard S. Smith III, Principal Investigator
Mr. Scot R. Fries, Business Official
DOE Contract No. DE-FG03-93ER81492
Amount: $70,303

A magnetron phase-priming method, distinct from injection- or phase-locking techniques, will be explored in Phase I as a means of controlling the starting phase of magnetron arrays for use in radio frequency (RF) linear accelerators (LINACs) at high gains (low phase-priming RF power). Several innovative methods for assuring that the starting phase is accurately preserved throughout the pulse, including novel modulator concepts, will also be studied. Advantages of the approach include overall efficiencies twice those of competing approaches, low manufacturing and operating costs, and high reliability. The primary objective is to experimentally demonstrate the approach using a multikilowatt magnetron array.

Anticipated Results / Potential Commercial Applications as described by the awardee: This work will lead to a high-power demonstration in Phase II and application to an RF LINAC (e.g., the Next Linear Collider) in Phase III. Non-LINAC applications include high-power radars, ion cyclotron resonance heating for magnetic fusion, and military high-power microwave uses.

118

A Modified Inverse Free-Electron-Laser Accelerator--Omega-P, Inc., 2008 Yale Station, New Haven, CT 06520; (203) 432-4201
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG05-93ER81514
Amount: $75,000

During Phase I, design studies will be undertaken for a modified inverse free-electron-laser accelerator. In this device, electron bunches are trapped in the beat-wave potential well created when a strong electromagnetic wave propagates along a spatially-periodic wiggler magnetic field. The electromagnetic drive power is to be at a wavelength of under 2 cm, with a power above 10 MW. Modifications will be introduced that are expected to increase the acceleration gradient above the conventional value. These include operation near waveguide cutoff for the radio frequency driver, and near cyclotron resonance from an axial magnetic field. Preliminary estimates show that these measures could allow a compact, inexpensive accelerator to be built to furnish a low-emittance 5 to 35 MeV electron beam having at least 10^9 particles in a 5 ps bunch. In Phase II, it is planned to build a demonstration model of such a machine.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful results from this study will show that a compact, inexpensive (under $1M) electron accelerator can be built for use in advanced accelerator research and development laboratory experiments. Uses in biomedical research and radiation source development are also possible.

119

Improved Sources of Spin-Polarized Electrons--
Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Stanley M. Vernon, Principal Investigator
Mr. Patrick N. McDonnell, Business Official
DOE Grant No. DE-FG02-93ER81621
Amount: $74,695

Photocathodes that produce polarized electrons are a vital component of the electron colliders used in high energy physics experiments, such as those at the Stanford Linear Accelerator Center (SLAC). The yields of electrons from today's photocathodes are low, reducing the effectiveness of these sophisticated linear accelerator instruments. This project should improve polarized electron sources by optimizing the deposition process used to make the photocathode layered structure. The basic device structure consists of a thin, strained layer of gallium arsenide (GaAs), on a gallium arsenide phosphide (GaAsP) buffer region, on a GaAs wafer. Careful design optimization is needed to achieve maximum layer strain, and therefore maximum yield of polarized electrons. Too much strain results in crystal defects which significantly reduce performance. In Phase I, structures will be formed by metal organic chemical vapor deposition (MOCVD); device performance will be measured at SLAC. Phase II will seek to improve upon results by studying more advanced layer structures and device processing, and deposition on larger diameter wafers.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned research could result in technology for production of highly polarized electron sources. These photocathodes are useful for all electron collider facilities, for low energy physics experimentation, and in such commercial applications as polarized electron microscopes. Reliable spin-polarized photo-emission sources could become available through sale of epitaxial wafers.

HIGH ENERGY PHYSICS DATA PROCESSING AND DETECTOR INSTRUMENTATION

120

Compact, High Density Analog to Digital Readout Circuits for Silicon Microstrip Detector Arrays--
Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523; (914) 592-1190
Dr. Elie Track, Principal Investigator
Dr. Hollis L. Caswell, Business Official
DOE Grant No. DE-FG02-93ER81639
Amount: $74,797

The current implementation of readout circuits for silicon microstrip detector arrays involves the use of one amplifier and one comparator detector. As the density of the arrays increases, the complexity, size, power dissipation, and cost of this approach increase and may become prohibitively high. A novel readout circuit that accomplishes the same function while eliminating the amplifiers and significantly improving the power dissipation and density is the goal of this project. The approach is based on using superconducting quantum interference devices (SQUIDs) to detect the output of the silicon strip detectors. The voltage signal from the SQUID appears as a digital signal through the Josephson voltage-to-frequency relation. The string of single flux quantum (SFQ) pulses generated by the SQUID is then synchronized, counted, and read out using superconducting electronics circuits. The complete readout circuit is implemented monolithically on a single substrate. The method amounts to a complete integrated analog to digital convertor (ADC) with pipeline storage. The ADC will have a full scale range of 0 to 640 nA. This sensitivity will eliminate the need for preamplifiers, and provide a digitized output of the number of electrons over the sample interval with 250 electrons resolution. The ADC design is compact (less than one mm^2) and extremely low-power (less than one mW). This will allow the integration of 500,000 readout channels with the same number of silicon microstrip detectors. To simplify the interface, a serial readout method allowing multiple chips to be read out on a single high wire is planned. Alternatively, the ADC can be integrated with a shift register-based first-in first-out storage on-chip for later readout. Superconducting logic can also implement one or more digital comparators providing a binary hit/no hit digital output, and the threshold data can be loaded by a single serial wire. Phase I will demonstrate the feasibility of the approach by demonstrating the voltage-to-frequency conversion of the output of a SQUID. In phase II, a complete readout channel demonstrating the required sensitivity will be produced.

Anticipated Results / Potential Commercial Applications as described by the awardee: The project will enable efficient readout of very high sensitivity detectors without the use of preamplifiers. The initial application will be in high energy accelerators, but the technology will be applicable to all high sensitivity detectors in spectroscopy, metrology, and focal plane array imaging systems.

NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

121

Monolithically Integrated Detector Arrays--Advanced Research and Applications Corporation, 425 Lakeside Drive, Sunnyvale, CA 94086; (408) 733-7780
Mr. Everett E. King, Principal Investigator
Mr. Ed LeBaker, Business Official
DOE Grant No. DE-FG03-93ER81567
Amount: $75,000

This Phase I project will develop a detector technology for tracking particles close to the beam pipe in new generation accelerator experiments. High spatial resolution, high speed data readout, compact size, low power, and radiation hardness will be achieved by incorporating a high resistivity, detector grade, 300 μm thick wafer patterned with p+ detector elements into the radiation hardened, submicron Bond and Etchback Silicon On Insulator (BESOI) process. A process will be developed to fabricate interconnects between the buried detector junction elements and readout circuitry fabricated in the SOI film. Experiments will be performed to evaluate the impact on the detectors of using the radiation hardened composite metal oxide semiconductor (CMOS)/BESOI process to fabricate the readout circuitry. Phase I will demonstrate a circuit design/layout interface to translate detector readout circuitry into the integrated detector process. A detector pre-amplifier circuit layout will be modified to be consistent with the CMOS/BESOI design rules. SPICE (Simulation Program with Integrated Circuit Emphasis) simulations will be performed on both the bulk and SOI versions of the circuit to verify and compare performance specifications.

Anticipated Results / Potential Commercial Applications as described by the awardee: A capability to provide application-specific array substrates with customer specified detector elements processed in the bottom wafer and polysilicon interconnects already in place should be available at the end of Phase I. The design and process capability will be extended to prototype pixel detector arrays integrated with readout circuitry in Phase II.

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Diamond-Based Photomultipliers--Advanced Technology Materials, Inc., 7 Commerce Drive, Danbury, CT 06810; (203) 794-1100
Mr. George R. Brandes, Principal Investigator
Mr. Daniel P. Sharkey, Business Official
DOE Grant No. DE-FG05-93ER81596
Amount: $75,000

The unique properties of semiconducting diamond may be exploited to create a novel, high gain, low noise, stable, and compact photomultiplier (PMT). Existing PMTs are inadequate for many applications where sensitivity and gain must be combined with stability and reduced noise requirements. A novel approach to the development of a compact photomultiplier is planned which meets these requirements. The usual properties of semiconducting diamond and recent advances in the chemical vapor deposition of negative electron affinity (NEA) diamond will be used to create an extremely stable and sturdy electron multiplier (dynode). Phase I will optimize the growth of NEA diamond and determine the feasibility of such a device by fully investigating the multiplicative and emissive properties of the material. Phase II will extend the Phase I project to include fabrication and testing of a prototype PMT and gamma ray detector.

Anticipated Results / Potential Commercial Applications as described by the awardee: A successful demonstration of the properties of diamond dynodes will make likely the commercialization of diamond based PMTs. The commercial applications for high gain, compact, stable, low noise PMT-based detectors are many, particularly in positron emission tomography or single photon emission computed tomography detectors, pollution monitoring, laser radar, and absorption or emission spectroscopy.

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Gallium Arsenide Pixel and Microstrip Detectors--Detectronics, 2517 Regent Road, Livermore, CA 94550; (510) 455-6520
Dr. Ching Lin Wang, Principal Investigator
Dr. Helen F. Wang, Business Official
DOE Grant No. DE-FG03-93ER81486
Amount: $69,755

Gallium arsenide (GaAs) semi-insulator detectors are known to be more radiation resistant and faster than silicon (Si) semiconductor detectors. In the "current mode" operation, the slow component, attributed to holes, was found to be drastically reduced by neutron irradiation of the crystal. In fact, the generated recombination sites reduce the leakage current in GaAs, in striking contrast to the leakage current increase in Si caused by radiation damage. The fast electron component is nearly unaffected up to 10^{15} neutron/cm^2. In the "particle counting mode", charge trapping in GaAs surface barrier detector is expected to be eliminated by neutron irradiation in a similar fashion. Current Superconducting Super Collider (SSC) central trackers are Si pixel and microstrip detectors. At high luminosities ($>10^{33}$/cm^{2}s) Si detectors cannot handle the high counting rate and cannot withstand the large dose (100 kGy, or 3×10^{14} protons/cm^2), but GaAs detectors can be made ~10 times faster and are expected to work beyond 100 kGy. If the radiation environment is such that the Si detectors quit working within a year, the GaAs detectors are expected to work beyond 10 years, possibly outlasting the SSC life, and can also handle the counting rate adequately. It is therefore important to explore pixel and microstrip detectors based on GaAs technology. The planned GaAs pixel is a prototype hybrid detector made by joining the independently fabricated, neutron-treated single GaAs cell (50 µm x 150 µm and 150 µm thick) and a composite metal oxide semiconductor integrated circuit by a metallic bond. In Phase I the pixel will be fabricated, the detection efficiency, charge trapping, radiation resistance, and speed of this detector will be studied, and the applicability of the technology to multiple arrays of pixel and microstrip detectors will be assessed. Very high speed and radiation hard pixel and microstrip detectors are expected to have significant commercial applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: The prototype single cell GaAs pixel or microstrip detector is expected to have much greater radiation resistance and higher speed than the corresponding single cell Si pixel detector. The technology will be extended to multiple arrays of pixel or microstrip configuration. There is an existing market world-wide for radiation hard, high speed pixel or microstrip detectors for high energy physics, nuclear physics, plasma physics, and nuclear power communities.

ACCELERATOR TECHNOLOGY FOR NUCLEAR PHYSICS

124

An Extended Interdigital Niobium Superconducting Linac Structure for Low Velocity Heavy Ions--AccSys Technology, Inc., 1177A Quarry Lane, Pleasanton, CA 94566; (510) 462-6949
Dr. James M. Potter, Principal Investigator
Dr. Marianne E. Hamm, Business Official
DOE Grant No. DE-FG03-93ER81565
Amount: $74,925

The use of the radio frequency superconducting ion linacs has grown steadily over the past 15 years, primarily for applications in nuclear and atomic physics where flexibility in ion species and energy are required. This technology continues to be actively developed at several laboratories worldwide. A recent development at the Argonne Tandem Linac Accelerator System (ATLAS) for the new positive ion injector is the low velocity interdigital structure. This simple structure can be extended, through several innovations now being considered, to lower cost per volt of acceleration with even lower velocity heavy ions. The primary objective of this study will be to generate the design of an optimized extended interdigital superconducting structure for use in nuclear physics research and industrial applications. Phase I will establish the operating regime for the extended interdigital structure and variations of it that include radio frequency quadrupole-like focusing to increase the beam dynamics performance. The planned development study will use the experimental results of a simple superconducting interdigital structure to develop an extended interdigital structure for use in nuclear physics applications for very low velocity heavy ions.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful demonstration of this new structure as a cost effective superconducting linac would have an impact on the development of a radioactive ion beam facility, and would be a candidate for high energy ion implantation applications. This commercial application requires continuous heavy ion beams with low charge states, and the size and operational cost of such a stand-alone accelerator system is of importance. The superconducting linac structure planned in this work would make such a system feasible.

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A 100 Gigahertz Acquisition of Bunch Profile, Position, and Arrival Time for Particle Accelerator Diagnostics and Control--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523; (914) 592-1190
Dr. Sergey Rylov, Principal Investigator
Dr. Hollis L. Caswell, Business Official
DOE Grant No. DE-FG02-93ER81638
Amount: $74,790

This project will develop an acquisition system that can capture every Superconducting Super Collider (SSC) beam bunch and measure in real-time: beam current profile captured at 100 gigasamples (GS)/s with 6-bits of resolution, bunch time of arrival to 10 ps relative to a synchronized master clock, and beam position to 25 microns every 10 ps. The system uses pickup coils along the beam axis. One set of pickup coils is connected to a superconducting 100 GHz digitizer which will acquire 24 samples of 4-bit deltas representing the change of current induced in the pickup coil by a beam bunch. Two more identical digitizers are connected to differential X and Y axis pickup coils. These will acquire 24 samples each representing the change in position of the beam current bunch with a 25 micron resolution every 10 ps, and thus will measure deviation within a bunch. A separate circuit will measure the time of arrival of a bunch with 10 ps resolution and generate a 32-bit time stamp relative to the entire SSC ring cycle time. The proposed digitizer is based on a superconducting 4-bit differential 100 GS/s flux-quantizing analog to digital convertor (ADC). The beam profile and position is acquired continuously until a trigger event is generated by the threshold level detection of a beam bunch. The trigger is used to make a snapshot copy of the last 24 samples in memory. The data are copied into another shift register for read-out before the next bunch arrival (16 ns).

Every bunch profile is stored in external memory for analysis. The projected size of the complete digitizer chip would be one cm^2 and will dissipate approximately one mW. Multiple channels can be synchronized by a single 10 GHz clock. The expected cost for all 800 niches in the SSC design is estimated to be less than \$1000 to \$2000 per niche. The Phase I objectives are to demonstrate the high speed performance of a 4-bit differential flux quantizing ADC and to produce and test this ADC at high speed with 10 words of storage.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned system will allow a precise monitoring of the beam characteristics of the SSC. This system performs functions that are currently unattainable (100 GS/s ADCs) with low-power (<one mW) and small size(<one cm^2). The ability to measure the profile, position, and time of arrival of every bunch at every niche in real-time should prove invaluable during the start-up and operation of the SSC or any of the other proposed accelerators.

126

An Intensity and Position Monitor for Particle Beam Diagnostics--Quantum Magnetics, Inc., 11578 Sorrento Valley Road, San Diego, CA 92121; (619) 481-4015
Dr. Alan L. Singsaas, Principal Investigator
Dr. Lowell J. Burnett, Business Official
DOE Grant No. DE-FG03-93ER81583
Amount: \$73,447

With the development of a new generation of accelerators employing superconducting magnets for nuclear physics such as the Continuous Electron Beam Accelerator Facility (CEBAF) and the Relativistic Heavy Ion Collider (RHIC), a corresponding need has arisen for a new generation of diagnostic tools for nondestructively monitoring the intensity and position of the particle beams. A system that represents a new approach to the measurement technique for position and intensity monitoring is planned in this project. The operating principle of the system differs from existing thin-wire pickoff antennas tuned to detect the electric field from the beam in that the magnetic field from the current is measured directly in pickup loops. This is accomplished through the use of a closed superconducting loop, coupled to a superconducting quantum interference device (SQUID). Advantages of the proposed system include a much lower limit on measurement threshold and dynamic range due to the extreme sensitivity of SQUIDs for magnetic field measurements, and a greater flexibility for integrating the system into the beam pipe because of the small dimensions of the pickup loops. Phase I will determine the specifications for the planned system and investigate the feasibility of the technique. The goal of Phase I research is to develop a design for a prototype beam position and intensity monitor for use at CEBAF. Several tasks will be performed to test experimentally the feasibility of the technical approach in Phase I and to conduct an extended analysis of the capabilities of the system to perform its stated objectives. The final task in Phase I will be to complete the design of the system to be built in Phase II. This approach results in a state-of-the-art system that provides enhanced performance in critical areas over existing devices and is adaptable to a wide range of design parameters such as active probe dimensions and measurement sensitivity.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned position and intensity monitoring system for accelerator particle beams would provide enhanced performance over existing devices because of its increased sensitivity and greater adaptability to the needs of superconducting magnet accelerators such as CEBAF and RHIC, as well as future accelerators.

SPECIAL INSTRUMENTATION FOR NUCLEAR CROSS SECTION MEASUREMENTS

127

A High Resolution Multistop Time-to-Digital Converter--Charles Evans and Associates, 301 Chesapeake Drive, Redwood City, CA 94063; (415) 369-4567
Dr. Bruce H. Newcome, Principal Investigator
Dr. David A. Reed, Business Official
DOE Grant No. DE-FG03-93ER81569
Amount: $74,849

The goal of this project is development of a time-to-digital converter (TDC) optimized for time-of-flight energy and mass spectrometers. The TDC will combine 100 ps time resolution, 30 ns dead time, 2048 stops over a total time interval longer than 100 ms, and an average data rate limited by bus speed. The TDC will accommodate auxiliary data arriving in coincidence. It will conform to one of the module interconnect standards, such as FASTBUS, CAMAC, or VME. During Phase I the interpolator section of the TDC will be designed, built, tested, and optimized. Several possible TDC features such as multiple inputs, multiple channels, and on-board intelligence will also be evaluated in order to define the TDC configuration that will be built in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of the planned TDC will advance the resolution of time-of-flight energy and mass spectrometers while allowing high data rates. Such spectrometers are used in both governmental and commercial laboratories.

PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

128

A Vapor-Grown, Carbon Fiber-Reinforced Beryllium Composite for Plasma Facing Material--Applied Sciences, Inc., 141 West Xenia Avenue, P.O. Box 579, Cedarville, OH 45314; (513) 766-2020
Dr. Jyh-Ming Ting, Principal Investigator
Mr. Max L. Lake, Business Official
DOE Grant No. DE-FG02-93ER81547
Amount: $74,853

Beryllium (Be) is a candidate material for diverters in nuclear fusion reactors. However, the use of Be is limited by its moderate thermal conductivity (218 W/m-K) and brittleness, both of which result in a low thermal shock resistance. The moderate thermal conductivity and poor mechanical strength also place a limitation on the thickness of the Be component, in turn limiting the lifetime of Be diverter tiles. Carbon/carbon composites having much higher thermal conductivity and mechanical strength have been developed; however, carbon materials suffer from high physical and chemical sputtering erosion rates and high tritium retention. It is planned to develop a graphite-fiber-reinforced Be composite which will manifest the advantages of both Be and carbon/carbon composites, and which will ameliorate the disadvantages of either one. The graphite fiber proposed for use, called vapor grown carbon fiber (VGCF), has the highest thermal conductivity of all carbon fibers available, as well as lowest reactivity. The resulting material is anticipated to exhibit a thermal conductivity in excess of 800 W/m-K because of the use of VGCF, and a much higher mechanical strength because of the composite structure. In Phase I a rapid pressure infiltration technique will be used to fabricate the composites. Effort will be directed toward examining interphase formation, if any, between VGCF and Be, and demonstrating a VGCF/Be composite with improved thermal and mechanical properties. Thermal conductivity, fracture toughness, and microstructural analyses will be performed.

Anticipated Results / Potential Commercial Applications as described by the awardee: VGCF/Be composites having a thermal conductivity of 800 W/m-K or higher could increase the thickness of plasma facing tiles from 3 to 12 mm or more, as well as improve the mechanical properties with respect to pure Be. This composite would significantly enhance operation of fusion reactors such as the International Thermonuclear Experimental Reactor.

129

Radiation Resistant Radio Frequency Feedthrough Insulators for Fusion Applications--Composite Technology Development, Inc., 2400 Central Avenue, Suite H, Boulder, CO 80301; (303) 447-2226
Dr. James B. Schutz, Principal Investigator
Dr. Naseem A. Munshi, Business Official
DOE Grant No. DE-FG03-93ER81586
Amount: $75,000

The materials currently used for radio frequency (RF) feedthrough insulators are inadequate for future fusion devices such as the International Thermonuclear Experimental Reactor (ITER). These monolithic ceramics will lose their dielectric strength, and swell in the neutron fluences expected in ITER. This makes them extremely susceptible to brittle fracture, which can lead to catastrophic failure in the insulation. A ceramic matrix composite (CMC) material could provide the improvement in fracture resistance as radiation is added to the operation mode. In Phase I candidate CMC materials will be developed on the basis of performance to meet the stringent electrical, thermal, mechanical, and radiation resistant requirements. Emphasis will be given to processing technologies that can fabricate parts at near net shapes. Screening tests will be performed for electrical, mechanical, and thermal properties for preliminary design evaluation and selection for further development. Test plans for developing material properties and demonstrating prototype component performance of these materials before, after, and during irradiation will be prepared for Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: This effort will lead to the development of a CMC material for RF feedthrough insulators suitable for use in fusion reactors such as ITER. A material which meets the harsh environment of a fusion reactor can also find applications in space-based and particle accelerator technologies, as well as the automotive and aerospace industries for engine parts.

130

Helium-Cooled Divertors with Low Activation Materials and Simple Fabrication Techniques--Creare, Inc., P.O. Box 71, Hanover, NH 03755; (603) 643-3800
Dr. Michael G. Izenson, Principal Investigator
Mr. Robert A. Hickin, Business Official
DOE Grant No. DE-FG02-93ER81628
Amount: $74,990

Helium cooling is attractive for high heat flux components in tokamak fusion reactors because there are large safety advantages compared to water coolant. However, current technology for helium cooling is hampered by the complexity of the housing required to provide helium to the normal flow heat exchanger and by the use of materials which become highly radioactive when operated in the environment of a tokamak divertor. This project will develop technology to overcome these difficulties. Innovative and simplified fabrication methods will be developed for the normal flow heat exchanger which can easily be scaled up to a full size divertor panel. These simplified fabrication techniques are made possible because the heat exchanger housing will be made from high performance materials such as an ordered intermetallic alloy of titanium aluminide. The heat exchanger will be fabricated entirely from low activation materials like titanium and aluminum, so that the structure will not become highly radioactive in a tokamak's neutron flux. Phase I is designed to prove the feasibility of this concept by demonstrating the key fabrication methods, and analyzing the helium flow and heat transfer in the normal flow heat exchanger to show that effective cooling is possible in the new configuration. In Phase II large-scale test models for performance testing in electron beam test facilities will be designed and fabricated.

Anticipated Results / Potential Commercial Applications as described by the awardee: This program will develop technology for helium cooled divertor panels in large tokamak reactors. These divertor panels will be simple to fabricate and be constructed from low activation materials. A key application is fabricating large-scale engineering test models of high heat flux components for the International Thermonuclear Experimental Reactor. The heat exchanger can be used for numerous high heat flux applications, including thermal management for fusion reactor first walls, hypervelocity vehicles, cooling of x-ray targets, and cooling high heat flux electronics components.

131

Methods of Improving Internal-Tin Niobium-Tin for Fusion Applications--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-93ER81513
Amount: $74,982

It has been reported that, when a tin bronze containing a small percentage of germanium is used to replace the normal tin bronze as the matrix in the bronze process for the manufacture of niobium-tin (Nb_3Sn), the critical current (J_c) is increased by a factor of ten in the field range 8 to 16 T. This project will compare the J_c properties of internal-tin Nb_3Sn made from a matrix containing a small quantity of germanium with those from a material with a pure copper matrix. Since the principal need is to increase the J_c in the higher field region, the effect on material with Nb 7.5 weight % tantalum (Ta) and Nb 1 weight % Ta as well as pure Nb filaments will be examined. In Phase I, trial billets will be prepared from material with a pure copper matrix to provide baseline comparisons. The principal investigation will be carried out on billets with copper germanium matrices and the three filament compositions mentioned above. The rate of strain hardening of alloyed matrices is expected to be higher than that of pure copper and, in the past, problems have been encountered when attempts were made to cold bond hard subelements in the tin-core process. The tubular-tin-source (TTS) process, has been shown to be far less sensitive to the hardness of the matrix when a hot isostatic pressing step is used in the processing of the core. The TTS process has, therefore, been chosen for this preliminary work, but Phase II will investigate the suitability of germanium alloyed matrices for the tin-core Nb_3Sn process.

Anticipated Results/Potential Commercial Applications as described by the awardee: This work should result in the development of an improved material for the International Thermonuclear Experimental Reactor and other fusion magnets. Also, the material will exist for high field magnets for high energy physics applications. In the commercial area, the improved material that will result from this work will be available for use in high field laboratory magnets.

132

Advanced Ultrasonic Methods for the Nondestructive Evaluation of Bond Quality in Brazed Composite-Metal Joints--Karta Technology, Inc., 1892 Grandstand, San Antonio, TX 78238; (210) 681-9102
Dr. Satish M. Nair, Principal Investigator
Dr. G. P. Singh, Business Official
DOE Grant No. DE-FG05-93ER81647
Amount: $74,974

A nondestructive ultrasonic method capable of quantitatively evaluating the bond strength and residual interface stresses at brazed joints, such as carbon/carbon-copper used in fusion reactor first wall structures, is planned. The mechanical properties at the interface control the intimacy of contact. By examining the boundary conditions the bondline properties may potentially be evaluated. Two innovative ultrasonic methods are planned for the feasibility study in Phase I. The first one involves guided waves travelling along the interface; the effect of bonding intimacy will be measured using the velocity and the attenuation characteristics of the ultrasonic wave. The second method uses ultrasonic waves which are normally incident to the bondplane; the frequency characteristics of the reflection/transmission coefficients at the bondplane will be used. Both these methods will be explored through initial modeling and experimental studies. The goal of the investigation is to select the optimal technique for hardware development in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: Brazed joints between high temperature composites and

metals such as copper, aluminum, etc., show significant potential for first wall structural applications in fusion reactors. It is anticipated that a portable, user-friendly, ultrasonic joint interface measurement device would help in evaluating the bond quality and consequently increase the reliability of such brazed structures. Applications also extend from utility industries to the composite intensive aerospace and defense sector where high speed applications require joints capable of withstanding elevated temperatures.

133

Ponderomotive Feedback Stabilization for Control of External Kink Modes and Disruptions in Tokamaks--Lodestar Research Corporation, 2400 Central Avenue, P-5, Boulder, CO 80301; (303) 449-9691
Dr. Daniel A. D'Ippolito, Principal Investigator
Dr. Richard E. Aamodt, Business Official
DOE Grant No. DE-FG05-93ER81587
Amount: $75,000

A novel approach to feedback control of external kink instabilities and plasma disruptions in tokamak magnetic fusion experiments will be investigated and the technical requirements for a feedback stabilization system relevant to the Princeton Beta Experiment (PBX-M) estimated. The work is based on the concept of ponderomotive stabilization of global magnetohydrodynamic (MHD) instabilities, which has previously been studied theoretically and demonstrated in magnetic mirror experiments. Calculations show that the ponderomotive force produced by several ion Bernstein wave (IBW) antennas can stabilize external kink modes in advanced tokamak regimes (e.g., high beta poloidal), but the required radio frequency (RF) power is severe without feedback. It is planned to investigate a feedback disruption control system in which the RF antennas would be modulated in response to the amplitude and phase of the unstable kink mode, thereby reducing RF power requirements for stabilization by two orders of magnitude according to preliminary estimates. In Phase I, the theory of ponderomotive stabilization will be reformulated to incorporate a simple feedback model, and preliminary benchmarking calculations for realistic PBX-M equilibria will be carried out using the Princeton MHD codes. If feasibility is established, a Phase II feedback system development effort and stabilization experiment will be planned to test the concept experimentally on PBX-M.

Anticipated Results/Potential Commercial Applications as described by the awardee: The Phase I research will determine the feasibility and general requirements of a ponderomotive feedback stabilization system for external kink and disruption control in tokamaks. In Phase II, the feedback system would be designed and tested experimentally on the PBX-M tokamak. This plasma control system would be particularly relevant to tokamaks such as the International Thermonuclear Experimental Reactor and the Tokamak Physics Experiment investigating the large bootstrap-current (high poloidal beta) regime relevant to long-pulse fusion reactors.

134

High Thermal Conductivity Graphite for the International Thermonuclear Experimental Reactor First Wall--Nuclear and Aerospace Materials Corporation, 16716 Martincoit Road, Poway, CA 92064; (619) 487-0325
Dr. Glen B. Engle, Principal Investigator
Dr. Glen B. Engle, Business Official
DOE Grant No. DE-FG03-93ER81493
Amount: $75,000

DOE needs to develop high thermal conductivity, irradiation stable first wall armor for the International Thermonuclear Experimental Reactor (ITER). A high thermal conductivity graphite will be developed in Phase I by adding metals in the premix during fabrication. Metals such as titanium, silicon, and boron that are known to form carbides will be used. The metal-loaded graphites will be heat treated to dissociate the carbides and deposit large "skeletal" graphite crystals in the microstructure to improve the thermal conductivity. Impregnation with high char yield pitches and infiltration with a hydrocarbon gas that deposits pyrolytic carbon will be used to improve density, thermal conductivity, and mechanical properties after formation of the graphites. The improved graphites will be characterized by measuring thermal and mechanical properties. The improved graphites will be evaluated for irradiation behavior. Selected structures will be identified in

Phase I for further study in Phase II. The most promising materials developed in Phase I will be irradiated during Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: A new graphite will be developed that will ultimately satisfy the thermal conductivity, mechanical properties, and irradiation stability requirements for ITER first wall components. The graphites developed in this project will find uses in other applications such as electronic components, heat exchanger pipes, space radiators, solar energy converters, and commercial heat exchangers.

135

A Neural Network-Based Disruption Alarm for Plasma Containment--Orincon Corporation, 9363 Towne Centre Drive, San Diego, CA 92121; (619) 455-5530
Dr. Gary L. Jahns, Principal Investigator
Mr. Richard L. Taylor, Business Official
DOE Grant No. DE-FG03-93ER81581
Amount: $74,308

Disruptions (sudden losses of plasma energy to the surrounding structure) degrade operating conditions and must be avoided in future large tokamaks. It is planned to study the feasibility of a disruption alarm system that would allow control measures to be invoked before a disruption occurs. In Phase I, a data set of parameter measurements from the Tokamak Fusion Test Reactor (TFTR) will be created, and these data will be used to train a neural network to distinguish between discharges that disrupt operation near the high-beta limit of operation and those that remain stable. Examination of the network stimulus-response relationship will reveal which parameters provide a signature for an impending disruption. Adaptive signal processing techniques will be used to extrapolate parameter evolution. It is planned to determine whether high-beta disruptions can be predicted from parametric data, and to identify the parametric relationships that provide a signature of impending disruption. The results will be incorporated into the Phase II project of developing a system capable of providing a disruption alarm suitable for tokamak control applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is intended to ultimately develop a real-time disruption alarm as the input for a disruption control system. Such a system will be important in next-generation fusion systems such as the International Thermonuclear Experimental Reactor (ITER) program, in which disruptions would threaten the structural integrity of the device.

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A Feasibility Study for an Electron Gun for a 5 Megawatt Free Electron Laser Using a Sheet Beam--Physical Sciences, Inc., 20 New England Business Center, Andover, MA 01810; (508) 689-0003
Dr. Michael E. Read, Principal Investigator
Dr. Merlin G. Miller, Business Official
DOE Contract No. DE-FG02-93ER81527
Amount: $75,000

A feasibility study of the generation of a sheet electron beam appropriate for a 5 MW cw, 150 GHz free electron laser (FEL) amplifier is planned in Phase I. The beam would have an energy of approximately 860 keV, and a current of 30 A. The electron gun, which will be a non-immersed planar Pierce type, will be examined in detail. A lower voltage, short pulse version will be designed for a proof-of-principle experiment of the FEL.

Anticipated Results / Potential Commercial Applications as described by the awardee: The results of Phase I will be a feasibility study and design of 860 keV sheet electron gun and collector for a 5 MW FEL based on a short period wiggler. The results of the study are also expected to be useful for extending existing designs for pulsed high voltage guns for cyclotron auto-resonance masers (CARM) to cw operation. Both the FEL and CARM would be useful in fusion applications such as electron cyclotron heating in the International Thermonuclear Experimental Reactor, and for other applications such as space based radar.

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Highly Efficient, Heat-Dissipating, Functionally Gradient Plasma Facing Materials--Plasma Processes, 7802 Hilton Drive, Huntsville, AL 35802; (205) 881-7572
Mr. Erin H. Richardson, Principal Investigator
Ms. Cheri M. McKechnie, Business Official
DOE Grant No. DE-FG05-93ER81563
Amount: $74,936

Currently, no single material satisfies all the design requirements for plasma facing components in magnetic fusion devices. Therefore, complex designs have been proposed and tested, but operation of the devices is still limited. Innovative techniques are planned in this project to fabricate functionally gradient high-Z (atomic number) to low-Z plasma facing materials incorporating active cooling, allowing for the selection of optimum materials in the optimum locations. Components will be fabricated utilizing vacuum plasma spray to form a gradient structure of copper to tungsten to low-Z boron and boron nitride in continuous gradients. The gradients will minimize differences in thermal expansion and lattice mismatch. The boron surface will minimize heavy metal particle impurities and can be nitrided to increase stability. Plasma facing components will be formed that feature highly efficient heat dissipation through integral cooling channels. The components will be designed so that there are no bondline interruptions between the plasma exposed surface and the cooling media. The Phase I efforts should demonstrate the ability to fabricate the functional gradients of the materials of interest; initial parameters will be investigated, and sample materials will be fabricated for Phase II characterization.

Anticipated Results / Potential Commercial Applications as described by the awardee: Functionally gradient, highly efficient, heat-dissipation materials and structures have immediate applications in magnetic fusion programs, rocket engines, aircraft and gas turbine engines, commercial power production, and in boilers and heat exchangers. The concept and materials also lend themselves to development of components with wear-resistant surfaces that can be used throughout U.S. industry (mills, pumps, engines, etc.).

138

Superconducting Wire with a Built-In Niobium Surface Coating to Limit Interstrand Eddy Currents in Cables--Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545; (508) 842-0174
Dr. Dingan Yu, Principal Investigator
Ms. Elaine Drew, Business Official
DOE Grant No. DE-FG02-93ER81533
Amount: $74,990

The stability and efficiency of large scale superconducting magnet systems often suffer from interstrand eddy current losses. There are drawbacks in the existing hard chrome plating technique when it is applied to niobium-tin (Nb_3Sn) strands. A new technique of developing a continuous, built-in niobium (Nb) coating on the surface of a superconducting wire will be incorporated into the manufacture of Nb_3Sn multifilamentary superconducting strands for the International Thermonuclear Experimental Reactor (ITER) project in order to simultaneously limit the interstrand eddy current losses in a superconducting cable and protect the copper stabilizer from residual resistivity ratio (RRR) degradation after reaction heat treatment. This project details the necessary steps to provide such a solution. In Phase I the feasibility of this technique will be evaluated by fabricating a prototype bronze-route Nb-coated Nb_3Sn wire and comparing the J_c and RRR performance of this wire with its counterpart wire without Nb coating. Moreover, this technique can also be applied to the manufacture of internal-tin route Nb_3Sn, niobium-titanium (NbTi) and other superconducting wires.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project should result in a new built-in Nb surface coating technique for fabrication of superconducting wire. Its success will speed up the progress of the ITER project, cut the cost of manufacturing superconducting strands, improve the stability of superconducting magnets, and reduce the interstrand alternating current losses. This technique can be used in the Superconducting Super Collider project and other applications.

139

Development of a Novel Brazing Material to Join Carbon-Carbon to Metals--Surmet Corporation, 33 B Street, Burlington, MA 01803; (617) 272-3250
Dr. Suri A. Sastri, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-93ER81623
Amount: $74,999

Joining carbon-carbon (C-C) composites to metallic alloys is important for DOE's Fusion Energy program. Use of current braze alloy technology produces joints with unbonded areas due to a lack of homogeneity of titanium in the alloy. This is a result of inherent limitations of the fabrication process. Unreliable braze joints made with the current braze alloys are not acceptable for the aggressive conditions encountered in the plasma-facing environments of a fusion reactor. An innovative approach to overcome this problem of active metal inhomogeneity in making novel braze alloys will be used. In Phase I of this project the optimum process parameters will be established and utilized to fabricate strips of a novel homogeneous braze alloy. Actual braze joints between C-C and niobium-1% zirconium alloy will be made and the feasibility of achieving fully-bonded joints in test coupons that can withstand thermal shock will be demonstrated using non destructive evaluation techniques, such as X-ray microfocus and laser pulse quench methods. Phase II efforts will address bonding of larger C-C tiles to metallic alloys to create fully dense and strong joints that can withstand the aggressive periodic high thermal flux environments of a fusion reactor.

Anticipated Results / Potential Commercial Applications as described by the awardee: Joining of non-metals to metals is a generic issue impacting many programs currently funded by DOE. The development of a new alloy with a homogeneous distribution of the active element that helps form sound braze joints will be a boost not only for use on C-C materials but also on a variety of other advanced ceramic and composite materials applications encompassing many industries.

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Development of an Electrochemical Infiltration Method for Carbon-Carbon Composite Surface Preparation--Surmet Corporation, 33 B Street, Burlington, MA 01803; (617) 272-3250
Dr. Suri A. Sastri, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-93ER81624
Amount: $74,998

The use of carbon-carbon (C-C) composites in many industrial applications has been limited due to difficulties in joining to other structural materials. Approaches using active braze alloys have met with limited success because of inhomogeneity of the braze alloy, wettability problems, and embrittlement of the joint. To overcome these problems a novel method for brazing C-C composites has been devised. The C-C surface is first specially prepared and then infiltrated to a depth of 15-40 microns with a non-carbide forming metal. The resulting surface zone, firmly bound to the C-C substrate, is a carbon fiber reinforced metal matrix composite suitable for brazing with conventional braze alloys. In Phase I, the feasibility of achieving fully-bonded C-C composite to a metal alloy in test coupons with the surface infiltration method will be demonstrated. Brazed joints will be evaluated using mechanical testing and non destructive techniques. Phase II efforts will consist of development of techniques for joining larger panels with appropriate testing in target fusion reactor applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: Joining of carbon-carbon to metals is an issue that impacts not only the fusion programs, but also many advanced materials programs currently sponsored at the national laboratories and in industry. The successful development of this novel braze technology for C-C composites will open a host of new applications for this important material.

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A Porous Metal Heat Exchanger with a Liquid Metal Coolant for Cooling Plasma-Facing Components--Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601; (717) 569-6551
Dr. John H. Rosenfeld, Principal Investigator
Mr. Richard W. Longsderff, Business Official
DOE Grant No. DE-FG05-93ER81645
Amount: $74,996

Divertor plates used in tokamak fusion devices can be subjected to heat fluxes of up to 1 to 5 kW/cm^2. Efficient cooling of these and other plasma-facing surfaces is necessary for reliable tokamak operation. The capability for porous metal heat transfer to handle heat fluxes as high as 6 to 8 kW/cm^2 has recently been demonstrated. These tests were conducted using water coolant in a copper heat exchanger. It is planned to extend this technology to liquid metal coolants in a high-temperature porous metal heat exchanger to provide efficient cooling at high temperatures and heat fluxes without water coolant. In Phase I, a porous metal cooled divertor design will be completed, and a technology demonstration test will be completed. For the Phase I test, NaK is proposed as the liquid metal coolant because of ease of handling; alternative coolants will be evaluated for use in Phase II. In Phase II, a representative porous metal cooled divertor plate prototype will be designed, built, and tested.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful development of this technology will allow tokamak plasma-facing components to be cooled efficiently using coolants other than water. This technology could also be useful for improving cooling of advanced nuclear reactors and other high heat flux applications.

FUSION ENERGY SYSTEMS

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An Innovative Approach for the Formation of Silicon Carbide/Silicon Carbide Composites--Lanxide Corporation, P.O. Box 6077, 1300 Marrows Road, Newark, DE 19714-6077; (302) 456-6216
Dr. William B. Johnson, Principal Investigator
Mr. Robert J. Ferris, Business Official
DOE Grant No. DE-FG05-93ER81517
Amount: $74,959

An innovative alternative for preparing silicon carbide (SiC)/SiC composites involves the DIMOX™ directed metal oxidation approach to form a SiC matrix. In the directed metal oxidation process a molten metal is oxidized to grow an oxidation reaction product into an adjacent preform of reinforcement material. Although this process is currently highly developed for aluminum oxide matrix materials, the proposed extension to the SiC matrix composite system is new and original. A carbon-bearing gas will be used as the reaction gas with molten silicon (Si) to grow to a SiC ceramic matrix. This gas must not decompose at the reaction temperature, and must react with molten Si to form SiC. One such class of gases, currently considered proprietary, has been tentatively identified. Phase I will include a complete survey of appropriate, commercially available carbon-bearing gases to identify the most promising alternatives from both thermodynamic stability and cost viewpoints. The gas showing the best combination of high stability, low cost, and fewest undesirable reaction products will be used as the "oxidant" to test the feasibility of forming SiC from molten Si both in the presence and in absence of a SiC particulate reinforcement phase. The products will be evaluated using weight change from the reaction, visual observation, x-ray diffraction, and optical and scanning electron microscopy of mounted cross-sections. The project offers the potential of providing inexpensive, dense, reinforced composites, and should allow for the fabrication of low cost complex components with desirable properties.

Anticipated Results/Potential Commercial Applications as described by the awardee: The SiC matrix materials to be developed here are under consideration for first wall, blanket, and divertor applications in plasma energy systems because of their low activation, short-term dose potential, low decay heat, and high temperature properties. This approach will provide more cost-effective materials with improved properties for this application compared to current approaches. Inexpensive SiC/SiC composites have multiple applications in the aerospace industry, e.g., as combustor and nozzle components in turbine engines. Their development would enhance the ability of the United States to remain the world leader in this increasingly competitive industry.

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Doping of Chemically Vapor Deposited Silicon Carbide to Enhance Thermal Conductivity--
Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706; (602) 574-1980
Mr. Prakash Arya, Principal Investigator
Dr. J. C. Withers, Business Official
DOE Grant No. DE-FG02-93ER81482
Amount: $$74,883

Silicon carbide-silicon carbide (SiC/SiC) composites hold significant promise for use in fusion energy systems. Even greater opportunity exists if the thermal conductivity of the chemically vapor infiltrated (CVI) matrix could be improved. It has been shown that the thermal conductivity of hot pressed SiC can be significantly enhanced using select dopants. This Phase I program will investigate the effect of select dopants on the thermal conductivity of chemically vapor deposited (CVD) SiC. The dopants will be codeposited and their concentration effects on the thermal conductivity of CVD SiC will be established. One dopant will be selected and further optimized with thermal conductivity measured to 1200°C. Feasibility will be demonstrated if the thermal conductivity of a CVI SiC matrix can be significantly enhanced through codeposition of dopants.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that the thermal conductivity of CVD SiC will be significantly increased, leading to applications in SiC/SiC composites as well as electronic substrates and packages, heat exchanger tubes, and a variety of thermal management uses.

PLASMA DIAGNOSTICS

144

A Versatile, High Pulse Energy, Subnanosecond Laser Source for Remote Plasma Diagnostics--
Light Age, Inc., 2 Riverview Drive, Somerset, NJ 08873; (908) 563-0600
Dr. Donald F. Heller, Principal Investigator
Dr. John C. Walling, Business Official
DOE Grant No. DE-FG05-93ER81633
Amount: $74,990

It is planned in Phase I to develop a high pulse energy sub-nanosecond laser source that can be used for a Thompson-Lidar backscattering diagnostic to map electron temperature and density in large-scale fusion plasmas. The source is capable of operation at repetition rates of 10 Hz and higher. This can increase by an order of magnitude the amount of critical data that can be obtained from a single tokamak experiment. The planned source will use high pulse energy alexandrite laser technology that has been developed over the last few years. To date there has been no successful application of this technology to sub-nanosecond, high energy pulses. The development effort is not necessarily straightforward. However, since the proposed high intensity source is both simple and tunable it can be used to generate light at almost any wavelength by nonlinear processes. Consequently, the same laser sources, or a reduced pulse energy version of them, can be used to generate tunable vacuum ultraviolet light for probing atomic and ionic densities in laboratory scale plasma experiments.

Anticipated Results / Potential Commercial Applications as described by the awardee: This source should fine broad application in the field of plasma diagnostics in a few large scale plasma laboratories. A scaled-down version of the technology developed here could provide a very versatile laboratory-scale diagnostic tool for the broader scientific market.

145

A Spectral Analysis Link Including an Innovative Fiber Optic Vacuum Feedthrough for Plasma Diagnostics for the International Thermonuclear Experimental Reactor--Physical Optics Corporation, 20600 Gramercy Place, Suite 103, Torrance, CA 90501; (310) 320-3088
Mr. Mark W. Foster, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-93ER81494
Amount: $74,978

DOE currently participates in planning the development of a demonstration fusion device known as the International Thermonuclear Experimental Reactor (ITER). In order to achieve the objectives of developing a physics and technology base for ITER design, very reliable and detailed measurement techniques for monitoring plasma behavior during all phases of operation are required. Among the many diagnostic techniques used to monitor specific plasma parameters is optical spectroscopy. One problem with implementing optical techniques is the collection of light and its delivery to remote spectral analysis equipment outside the reactor. Presently, optical fibers are being investigated for visible spectroscopy of the plasma because of their flexibility in delivering optical signals. In order to utilize fiber optics technology in the ITER reactor, both radiation-hard collection optics and high reliability fiber optic vacuum feedthroughs are required that can withstand the harsh fusion environment of the ITER. Simple fiber optic components integral to radiation hardened fibers will be developed in Phase I to demonstrate a fiber optic spectral analysis link that promises to meet diagnostic requirements of ITER. The planned fiber optic elements can be used both for sensor elements with high spatial resolution and as components in a multichannel fiber optic feedthrough capable of operating at temperatures above 450°C and pressures less than 10^{-11} torr.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful completion of this Phase I project will be the demonstration of novel fiber optic elements that can be used as spectroscopic sensors or components in a new fiber optic vacuum feedthrough. Future commercial applications for the sensors include remote spectroscopic monitoring of chemical facilities, hazardous waste sites, and the environment, as well as medical diagnostics. The vacuum feedthrough will fill a large void in the vacuum accessories market and significantly facilitate the application of fiber optics in high vacuum systems.

146

A Compact Extreme Ultraviolet Spectrometer with Spatial Resolution--PXL, Inc., 1 - H Deer Park Drive, Monmouth Junction, NJ 08852; (908) 329-0505
Dr. Alexander V. Vinogradov, Principal Investigator
Dr. Ada Suckewer, Business Official
DOE Grant No. DE-FG05-93ER81634
Amount: $74,513

The goal of this project is to develop a prototype of a high resolution, high throughput, near-normal incidence, compact spectrometer for diagnostics with spatial resolution of fusion plasmas. It is planned to use highly dispersive new miniature optical elements - sliced multilayers - in reflection and transmission modes instead of conventional gratings. Because of the extremely large angular dispersion of these components, the dimensions of the spectrometer will be dramatically decreased. A single-channel instrument will have a size of about five cm. Many of these miniature spectrometers can be assembled into a compact multichannel instrument providing spatial resolution of spectroscopic measurements. In Phase I, a feasibility experiment will be performed to demonstrate an expected intense first diffraction order for radiation in the range of 13 to 17 nm of the new dispersive element (sliced multilayer). The experimental data will allow comparison of the operational parameters of the spectrometer with present grazing incidence spectrometers.

Anticipated Results / Potential Commercial Applications as described by the awardee: The miniature size of the high throughput x-ray spectrometer will permit its use in multiple configurations, for miniature single channel to compact multichannel spectrometers with spatial resolution capability. It is anticipated that this instrument will find wide applicability in the diagnostics of fusion and laser produced plasmas, in astrophysics, in chemical and material sciences for analysis, and materials characterization (photoemission from solids for chemical analysis and band-structure studies, for instance).

147

A Passive Optical Monitor for Tokamak Plasma Inhomogeneities--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Stephen Fulghum, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-93ER81531
Amount: $74,945

A novel, inexpensive, and passive optical diagnostic for measurement of the scale size and flow velocity of tokamak plasma inhomogeneities has been developed. The diagnostic is based on an equal-path, lateral shearing interferometer and can be analyzed, in principle, as a form of Doppler velocimeter. This system requires only incoherent light emission from the plasma itself for operation. The diagnostic can be adjusted to respond primarily to inhomogeneities below a given scale size, moving along a given axis, within the limited focal volume of the collection optics. The information obtained is thus localized in three dimensions and is not a line-of-sight average. The resulting signal is digitized at MHz frequencies for the duration of a tokamak run and analyzed later with a fast Fourier transform. The peak frequency of the signal in a data segment, combined with the spatial scale size setting and the orientation of the sensing axis, determines the flow velocity of the plasma inhomogeneities in that time interval. Multiple sensing heads can be combined to provide information on the spatial scale size spectrum. Scale sizes from a fraction of a millimeter up to one cm can be resolved along with frequencies of up to several MHz. In Phase I the resolution and signal to noise expected in both the core and edges of the Alcator C-Mod tokamak plasma will be calculated. A new achromatic optical instrument using Ronchi gratings instead of a shearing interferometer to observe two scale sizes simultaneously will be fabricated and used on the C-Mod plasma. Finally, a preliminary design will be completed for a more advanced instrument to be fabricated and used in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: This instrument can provide both flow velocity and spatial scale from localized volumes within the plasma with less effort and a lower cost than competing techniques and will require less port space. Commercial systems could measure flows ranging from flames to highway traffic.

ROBOTICS AND REMOTE OPERATIONS IN CIVILIAN NUCLEAR REACTOR FACILITIES

148

An Advanced Graphical User Interface and Programming Environment for Nuclear Telerobotics Systems--Automatix, Inc., 755 Middlesex Turnpike, Billerica, MA 01821; (508) 667-7900
Mr. Joel Katz, Principal Investigator
Dr. John Agapakis, Business Official
DOE Grant No. DE-FG02-93ER81606
Amount: $75,000

The objective of this project is to develop an advanced programming environment for nuclear telerobotic systems that combines powerful graphical user interfaces, three dimensional modeling of robots and workcells, capabilities for on-screen graphical robot path generation, editing and simulation, integration of video feedback from the remote scene, and a novel robot programming scheme (macro programming). Macro programming refers to the generation of complex robot programs through hierarchical calls to primitives (macros) that encapsulate all the required motions needed to perform generic classes of operations and which can be programmed by teaching only a small number of key points. This approach has been already explored for the programming of welding robots in aerospace applications and has been shown to significantly improve the productivity and consistency of manual robot programming. Phase I tasks include a brief review of related work, an analysis of application requirements, development of a preliminary system design, and development and demonstration of breadboard prototypes of the planned concepts. In addition to the overall graphical user interface design and the telerobotic enhancements to the previously developed approaches for three dimensional modeling, display, and animation of robotic devices, graphical path generation and editing, and macro level programming, other issues to be addressed during the design and prototyping effort will include selection of an implementation and delivery platform and strategy, use of alternative user input and display devices, approaches for model interfacing with video feedback, and calibration to the real world. On the basis of the above work, needs for future research and development will be identified, and the Phase II effort will be planned.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned systems will improve the productivity and consistency of robotic systems programming in nuclear telerobotic applications. In addition to use in the nuclear industry, the proposed technology has significant commercial potential for use in other telerobotic and robotic applications.

149

An Improved Vision System for Teleoperated Platforms--Benthos, Inc., 49 Edgerton Drive, North Falmouth, MA 02556-2826; (508) 563-1000
Mr. William D. McElroy, Principal Investigator
Mr. Lawrence W. Gray, Business Official
DOE Contract No. DE-FG-02-93ER81524
Amount: $73,528

This project will evaluate the feasibility of integrating the visor portion of a commercially available personal video system with a six-axis head-tracking system recently developed for personal computer use, to provide a cost-effective visor vision system for teleoperated vehicles. Teleoperation of air, land, and underwater vehicle platforms requires a high level of operator interaction. Most systems currently use video monitors, which require the operator to remain in a relatively fixed position to monitor video feedback, even while engaged in operating other system controls. The planned system would provide the operator with increased freedom of movement, as video feedback would be provided by a lightweight visor. The head-tracking element would further improve the operator's performance by translating movements of the head into platform control functions such as pan, tilt, focus, and zoom. For example, to pan the camera left or right, the operator would turn his or her head left or right. Improved vision systems such as helmet mounted displays and head-tracking systems currently available are both expensive and cumbersome. This integration of two commercially available products offers the potential for a cost-effective, ergonomically designed display and control system that would alleviate operator fatigue and increase the effectiveness of teleoperated platforms. The Phase I effort will determine the performance characteristics of, and integrate, the visor and the head tracker, and will develop control algorithms.

Anticipated Results / Potential Commercial Applications as described by the awardee: The federal government currently has several programs involving the design and production of teleoperated air, land, and sea platforms, virtually all of which would benefit from the development of an improved, cost-effective display and control system. The planned development can also be applied to commercial systems to upgrade existing vision systems.

150

Precision Moderate-Range Coherent Laser Radar for Telerobotics Using Eyesafe Diode-Pumped Lasers--Lightwave Electronics Corporation, 1161 San Antonio Road, Mountain View, CA 94043; (415) 962-0755
Dr. Thomas J. Kane, Principal Investigator
Dr. Richard W. Wallace, Business Official
DOE Grant No. DE-FG03-93ER81490
Amount: $74,916

A fast, accurate, compact, and radiation-immune system for range measurements at short and moderate range would be useful in many industrial applications, including hazardous work in high-radiation environments. This project will investigate a system that could significantly advance the state of the art in precision optical ranging at moderate range. The system would be a continuous wave (CW) coherent laser radar based on the eyesafe, very long coherence length lasers which have already been developed. The system would make use of optical fiber, and would be designed so that all the lasers and electronics would be remote from the measuring head. The measuring head would contain only passive optical components, and would be low cost and radiation immune relative to the remote opto-electronic components. The type of laser radar to be used would be a coherent CW tone-modulated radar with the tone frequency adjusted to phase-lock the return signal to the outgoing signal. Heterodyne detection would be used, and the unmodulated part of the return signal would be used as a phase reference for phase locking. During Phase I, this system would first be modeled, and then a benchtop prototype built. A diode-pumped single-frequency laser would be built at 1415 nm, which is an ideal laser radar wavelength.

Anticipated Results / Potential Commercial Applications as described by the awardee: After the feasibility of an eyesafe coherent laser radar is established, this system would be developed and engineered into a phonebook-sized "opto-electronic processing box" connected by fiber optics to a 10-cm by 2-cm tube which would be the "measurement head." During Phase III, the additional interfacing and packaging needed for productization would be completed. The products should find uses in the nuclear and civil engineering industries as ranging systems in robotic vision and surveying.

151

An Integrated Video and Gamma Ray Imaging System for Robots in Nuclear Environments--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Dr. Michael R. Squillante, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-93ER81530
Amount: $75,000

Robots are becoming increasingly important throughout the nuclear industry. They are commonly used to improve operations and maintenance, lower operating costs, enhance worker safety, and reduce radiation exposure to workers. However, the capabilities of existing robots are limited by the systems used to sense their surroundings. Although existing robots often have visual imaging systems and nuclear survey instruments, these sensors do not allow the robot or the operator to easily visualize the distribution of radioactivity around the robot. Instead, time-consuming scanning procedures are required to locate and quantify sources of radioactivity in tasks such as surveillance and inspection of nuclear plants, clean operations, and the routine processing of nuclear materials. Phase I will develop a very compact camera system which will be able to generate a real-time image of the nuclear radiation in the camera's field of view. The resulting image, which can be superimposed on a visual image, will allow the operator to quickly and easily identify the location of sources of nuclear radiation and to measure the intensity of the radiation. Such a capability would be immediately beneficial for robotic and telerobotic operations in nuclear environments.

Anticipated Results / Potential Commercial Applications as described by the awardee: The capabilities of existing robots are restricted by their limited ability to sense their surroundings. Successful completion of this research will result in a compact sensor which generates a real-time image of nuclear radiation superimposed on a video image. This will significantly enhance the ability of robotic and telerobotic systems to quickly and rapidly locate sources of nuclear radiation in the nuclear industry. Such a sensor would find widespread use in present-day robotic applications. The sensor could also be modified for use as a portable radiation imaging device, where it would find widespread use in locating and monitoring radiation wherever nuclear radiation is used.

TECHNOLOGY FOR SPACE NUCLEAR PROPULSION AND POWER

152

Multilayer, Quantum Well Layer Film Thermoelectrics--Hi-Z Technology, Inc., 6373 Nancy Ridge Drive, San Diego, CA 92121-2247; (619) 535-9343
Mr. Norbert B. Elsner, Principal Investigator
Mr. Norbert B. Elsner, Business Official
DOE Grant No. DE-FG03-93ER81574
Amount: $75,000

Thermoelectric materials are used in a variety of power sources and Peltier refrigerators. The dimensionless figure-of-merit (ZT) is used as a measure of the relative effectiveness of these materials. The best known materials have ZTs of less than one. New solid state theory predicts that multilayer-quantum well films could have ZTs greater than six. In Phase I such materials will be produced by alternately depositing a quantum well layer of a thermoelectric material and a suitable barrier layer. Evaluation of these materials will consist of measurement of Seebeck coefficient, resistivity, and thermal conductivity, as well as a direct measurement of Z. Transmission electron microscopy will be used to evaluate the other material characteristics.

Anticipated Results / Potential Commercial Applications as described by the awardee: A ZT of about two should be achieved which will double the conversion efficiency. Large gains in waste heat recovery via thermoelectrics would be realized.

153

A High Repetition-Rate, High Power, All-Solid-State Pulsed Driver for Electrodeless Inductive Thrusters--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Xing Chen, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-93ER81532
Amount: $74,940

The objective of this project is the development of high power, long life, high impulse thrusters for nuclear electric propulsion. The pulsed electrodeless inductive thruster has several advantages including an ultralow erosion rate, long thruster life, and high power capability. The performance of present inductive thrusters has been hindered by the lack of reliable, efficient, pulsed-power technology. Novel all-solid-state pulsed drivers have recently been developed that have lifetimes of greater than 10^{11} pulses and can operate at repetition rates of 10 KHz. These high power pulsed drivers can be designed to generate the optimal pulse shape that is required for rapid gas breakdown, efficient plasma acceleration, and recovery of the reflected electrical energy. Major benefits derived from these all-solid-state pulsed drivers include higher power capability, lower specific mass, longer lifetime, and increased energy efficiency. The total impulse of an all-solid-state inductive thruster is projected to be 10^8 to 10^9 N-sec as compared to 10^6 N-sec for conventional electric thrusters. The objective of the Phase I effort is to determine the technical feasibility of powering inductive thrusters using a modular design. Such a design will incorporate several all-solid-state drivers operating in parallel to achieve megawatt average power required for nuclear electric propulsion.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful completion of this program will lead to the development of a novel thruster technology that can be scaled to the multimegawatt average power level required for nuclear electric propulsion. The high power all-solid-state thrusters will increase the total integrated impulse by a factor of 100 to 1000 over conventional electric thrusters, while reducing specific mass to below 0.5 kg/kW. Also these thrusters require significantly less fuel mass which translates into a cost saving of 20% for delivering pay loads into space.

154

In-Situ Electrical Testing of Multicell Thermionic Fuel Elements--Space Exploration Associates, Inc., 141 West Xenia Avenue, P.O. Box 579, Cedarville, OH 45314; (513) 766-2050
Mr. Arnold Kalandarishvili, Principal Investigator
Mr. Max L. Lake, Business Official
DOE Grant No. DE-FG02-93ER81549
Amount: $74,552

In Phase I an in-situ method is presented for electrically heating emitters of multi-cell in-core thermionic fuel elements (TFEs). Nuclear heating is not required. This is accomplished by supplying pulses of electric current to momentarily bias the collectors in the TFE with a several-volt negative voltage. Electrons are emitted from the nominal collector via Schottky emission and heat the emitter via electron bombardment heating. No other known method, other than inserting the TFE in a nuclear reactor, can be used to test the operating characteristics of an in-core TFE prior to reactor integration.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will allow non-nuclear heating of multicell TFEs. This will greatly improve the ability to pre-test and qualify reactor cores based on such TFEs. This is important not only for U.S. Government applications, but also for civilian applications such as communications, high definition TV broadcast, and others.

155

Indium Gallium Arsenide Thermophotovoltaic Energy Converters--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Steven J. Wojtczuk, Principal Investigator
Mr. Patrick N. McDonnell, Business Official
DOE Grant No. DE-FG02-93ER81619
Amount: $67,820

Thermophotovoltaic indium gallium arsenide (InGaAs) cells are proposed for converting energy from a radioisotope power source, the general purpose heat source (GPHS), into electricity with conversion efficiencies considerably higher than those obtained with thermoelectric generation. InGaAs is a ternary semiconductor alloy whose bandgap can be varied from 0.36 eV to 1.42 eV. The 0.74 eV $In_{0.53}Ga_{0.47}As$ composition is particularly useful since high quality InGaAs can be grown lattice-matched to indium phosphide (InP) wafers, resulting in good p-n junctions and high converter efficiency. This 0.74 eV bandgap is too high for efficient thermophotovoltaic conversion with the 1100°C GPHS. A bandgap of 0.5 eV would deliver twice the power if it were not for defects created when InGaAs is grown mismatched. An optimization study of this tradeoff between cell degradation due to mismatch and the increased output power possible by matching the cell bandgap to the GPHS radiation spectrum is planned in this project. Phase I will grow InGaAs with bandgaps of 0.74, 0.70, 0.65, 0.60, 0.55, and 0.50 eV, fabricate cells, and test them to determine the relative degradation of the cells as the InGaAs composition is moved away from an exact lattice-match to InP. In Phase II, the Phase I cell that delivered the highest output power under the GPHS radiation will be experimentally developed into a prototype power converter. In Phase III, a converter will be developed for a specific mission.

Anticipated Results / Potential Commercial Applications as described by the awardee: The anticipated result of the project is a new, more efficient way of producing electrical power from a radioisotope source. The major application is expected to be long-lifetime power sources, especially for low-light applications where traditional photovoltaic cells are not appropriate.

156

An Innovative Cesium Supply for Hybrid Thermionic Reactors--Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601; (717) 569-6551
Dr. Kevin Horner-Richardson, Principal Investigator
Mr. Richard W. Longsderff, Business Official
DOE Grant No. DE-FG05-93ER81644
Amount: $74,973

Recently proposed hybrid thermionic nuclear space power systems have been given much attention due to the benefits of the dual mode of operation. A hybrid reactor system can provide electric power for on-board requirements through the thermionic converters as well as propulsion through direct in-core thermal heating of hydrogen. This concept improves capabilities of future space missions, but places new requirements on the thermionic converters and their components including the cesium supply reservoirs. In the propulsion mode of operation significant quantities of hydrogen permeate into the interelectrode gap of the converters. The cesium source for the converters must effectively remove this gas from the interelectrode gap. The Phase I program objective is to develop an innovative cesium source that is able to continuously sweep large quantities of contaminant gases from the interelectrode gap and that provides improved cesium vapor control over current cesium sources for thermionic converters.

Anticipated Results / Potential Commercial Applications as described by the awardee: Success in the proposed development will improve reliability and efficiency of thermionic converters, particularly hybrid reactor designs, through the development of a reliable cesium source capable of maintaining optimum cesium pressure over a broad range of reactor fluctuations. The innovation is expected to improve the integration of thermionic converters in space nuclear power plants and will benefit future commercial and military space exploration and utilization.

157

Low Bandgap Thermophotovoltaic Devices for a General Purpose Heat Source--United Solar Technologies, Inc., 522 Dover Point, NE, Olympia, WA 98506; (206) 705-2000
Dr. Peter E. Gruenbaum, Principal Investigator
Mr. Richard J. Kelley, Business Official
DOE Grant No. DE-FG03-93ER91650
Amount: $74,822

Radioisotopes have been used as a source of energy for space applications where there is insufficient solar energy to use standard photovoltaic arrays. Thermophotovoltaic (TPV) systems using gallium antimonide (GaSb) photovoltaic cells have been proposed as a way to increase the efficiency of the thermal-to-electric conversion. However, GaSb does not absorb most of the blackbody spectrum emitted from the general purpose heat source (GPHS) operating at 1100°C. In order for the system to be efficient, the majority of photons must be reflected back onto the heat source, reabsorbed, and re-emitted at higher energy. This requires that the entire system be highly reflective; any "parasitic absorption" severely degrades the efficiency and lowers the GPHS temperature. TPV cells with a lower bandgap will be fabricated in Phase I from gallium indium antimonide (GaInSb) in order to absorb a larger proportion of the blackbody spectrum. The additional energy conversion will be demonstrated to result in an increased efficiency for any system with parasitic absorption of over 5%. For systems with 15% parasitic absorption, the efficiency increases from 16% (using GaSb) to 18% (using GaInSb).

Anticipated Results / Potential Commercial Applications as described by the awardee: GaInSb cell receivers can be used to replace thermoelectric converters in radioisotope power generators to achieve a factor of three increase in system efficiency. Several space programs would benefit from the higher performance offered by these TPV converters. In addition, these cells can be used in conjunction with cogenerative solar photovoltaic/thermal concentrator systems.

TECHNOLOGY TO SUPPORT AND IMPROVE NUCLEAR FUEL CYCLE PROCESSES

158

Incorporation of Reliability, Availability, and Maintainability Analysis Techniques into Simulation Modeling--JBF Associates, Inc., Technology Drive, 1000 Technology Park Center, Knoxville, TN 37932-3353; (615) 966-5232
Mr. Vernon H. Guthrie, Principal Investigator
Mr. David F. Montague, Business Official
DOE Grant No. DE-FG05-93ER81646
Amount: $74,972

The complex chemical and mechanical reprocessing facilities are made up of many systems and subsystems that must interact with each other. Simulation modeling is a useful tool for predicting how well systems and subsystems perform together to achieve a facility's defined reprocessing goal. However, with currently available simulation software it is very difficult to include specific failure and repair information in the simulation model. Not being able to include reliability, availability, and maintainability (RAM) considerations in a simulation model makes the results less accurate and potentially misleading. Therefore, it is planned to develop RAM interface software for personal computers that will help designers efficiently incorporate RAM techniques into existing process simulation software and provide RAM-based results needed to reduce the uncertainty in the performance of facility design (e.g., the expected throughput with failure and repair addressed). To determine the feasibility of developing such software, the following technical approach for Phase I will be used: (1) collect data on a reprocessing facility's design, operation, and maintenance and select a portion of the facility to study, (2) select a simulation software package that can easily exchange data with other software packages, (3) develop a RAM-analysis interface that communicates with the selected simulation software, (4) obtain RAM-based process simulation results for the example analysis, and (5) document the findings and conclusions on the feasibility of incorporating RAM analysis techniques into simulation modeling. Phase II will focus on developing RAM-interface software that can be used with a wide variety of simulation software packages. Phase III will focus on promoting wide use of the RAM interface software by offering a training course (perhaps 2 to 3 days) to teach design engineers how to develop input information, obtain the RAM-based results using the developed simulation software, and use these results for decision making.

Anticipated Results/Potential Commercial Applications as described by the awardee: The results of this work will benefit organizations designing reprocessing facilities as well as almost any other complex plant design activity where RAM analysis capabilities are important. Specifically, the proposed work should reduce the cost and schedule of reprocessing facility design activities and help ensure that facilities meet their reprocessing goals. The potential for long-range commercial development for this RAM interface software is high. A short training course for design engineers will ensure that the software will quickly become a useful tool for many designers who need accurate and timely RAM-based information on how their designs will perform.

159

Precision Machining of Integral Fast Reactor Metal Fuel Pins with Argon Cutting Jets--Quest Integrated, Inc., 21414 68th Avenue South, Kent, WA 98032; (206) 872-9500
Dr. Mohamed Hashish, Principal Investigator
Ms. Diana J. Suzuki, Business Official
DOE Grant No. DE-FG03-93ER81648
Amount: $68,952

High-velocity waterjets and abrasive waterjets have become viable precision cutting tools for a wide range of applications. This project addresses the use of argon liquid or gas cutting jets for fabricating the metal fuel pins used in the pyrometallurgical fuel cycle of advanced reactor concepts. Argon is an inert gas, and it is the ambient environment in the injection casting furnaces used for fuel pin fabrication. Thus, after cutting, no liquid residue will remain to require special handling. In Phase I, an experimental feasibility investigation will be conducted on the use of high-pressure (about 10 ksi) argon jets for cutting the fuel pins. An alternative material will be used that simulates the brittleness and other machining characteristics of the uranium-plutonium-zirconium alloy used in the pins. An experimental cutting system will be prepared to study the cutting capabilities of argon jets. Argon liquid, from commercially available containers, will be pumped up to about 10 ksi in pressure and propelled through specially designed small-diameter nozzles (about 0.005 inch) to form high-velocity cutting jets. The metastable liquid argon jet will be used to entrain abrasive particles such as garnet (or other compatible materials) in specially designed abrasive jet nozzles. The abrasive-argon jet will then be used as a precision machining tool to cut the fuel pin to length. An alternative approach of using the liquid argon jet to score the workpiece such that it can be snapped will also be evaluated. Temperature control of the upstream flow and nozzle geometry optimization will be used as strategies to manipulate the thermodynamic conditions of the argon jet. In addition to assessing the technical feasibility of the argon jet cutting, conceptual designs will be prepared on how the jet cutting technique will be interfaced with current fabrication hardware. Advanced prototype system development activities will be identified for fabrication, testing, and evaluation in Phase II. The remote operability and maintainability of the jet cutting method are significant advantages that will be evaluated in this project.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned work will lead to the development of a new jet cutting technique using liquefied gases in general. In addition to nuclear applications where inertness is critical, the cutting method will benefit applications where nonintrusive media are needed. Example potential commercial applications include uses in hazardous environments (e.g., cutting of propellants), jet-assisted machining, surface preparation, metal atomization, and cutting and cleaning inside aircraft and spacecraft.

ENRICHMENT OF URANIUM FOR CIVILIAN NUCLEAR POWER REACTORS

160

High Energy Density Ceramic Capacitors for Uranium Atomic Vapor Laser Isotope Separation--Cape Cod Research, Inc., 19 Research Road, East Falmouth, MA 02536; (508) 540-4400
Dr. Brian G. Dixon, Principal Investigator
Ms. Katherine D. Finnegan, Business Official
DOE Grant No. DE-FG02-93ER81607
Amount: $75,000

High energy density capacitors are needed to meet the demands of laser systems. Because capacitor design is a mature technology, improvements in performance of the size needed for tomorrow's lasers will likely come from improvements in ceramic formulation and manufacturing technology. Phase I addresses these two issues by experimentally exploring the feasibility of continuously coating metal foil with amorphous dielectric. The dielectric has the required combination of relatively high dielectric constant, very low loss, and very high breakdown strength.

Anticipated Results/Potential Commercial Applications as described by the awardee: Capacitors, piezoelectric devices, thermistors, varistors, and ferrites have world wide sales of over $4 billion. Improvement in the technology of manufacturing these ceramic products has great commercial potential, especially if the result is a less expensive and superior product.

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Aluminum Nitride Copper Laser Tubes--Cercom, Inc., 1960 Watson Way, Vista, CA 92083; (619) 727-6200
Mr. Andre Ezis, Principal Investigator
Mr. Richard Palicka, Business Official
DOE Grant No. DE-FG03-93ER81568
Amount: $75,000

Aluminum nitride (AlN), a high thermal conductivity electrical insulator, has gained acceptance in the electronics industry as a substitute material for aluminum oxide and beryllium oxide as heat sink substrates and in multilayer packages. Aluminum nitride is also a very chemically inert, resistant material at high temperatures. Potential uses range from immersion heater protection tubes for the aluminum die cast industry to copper vapor laser tubes. The majority of corrosion resistant applications require large, structurally reliable parts, as compared to the available electronic grades of AlN. This project will investigate the principles required to produce large statistically reliable structural shapes of AlN through in-process statistical control using novel low-cost furnacing concepts. In Phase I, test billets of AlN will be fabricated and characterized by measuring the modulus of rupture, Weibull modulus, density, microhardness, fracture toughness, and thermal conductivity, and the microstructural uniformity will be determined using optical and scanning electron micrography.

Anticipated Results / Potential Commercial Applications as described by the awardee: Uniform, reliable, and reproducible AlN copper laser tubes should result from the planned studies. In addition, the effort will provide the technology base for improved low-cost AlN heat sinks and electronic substrates.

162

A Narrow Linewidth Frequency Stabilized Microlaser--Laser Power Corporation, 12777 High Bluff Drive, San Diego, CA 92130; (619) 755-0700
Dr. Maurice Pessot, Principal Investigator
Dr. Douglas H. Tanimoto, Business Official
DOE Grant No. DE-FG03-93ER81578
Amount: $72,931

For accurate referencing of laser sources used for isotope separation, the uranium-atomic vapor laser isotope separation (U-AVLIS) program requires narrow linewidth wavelength standards in the visible-near infrared (IR) region of the spectrum. A novel approach based upon advanced solid-state microlaser technology is planned to satisfy this requirement. The design utilizes a diode pumped electro-optically tunable monolithic microlaser that allows for fast control of the cavity resonance frequency. Thus, the frequency can be tuned/scanned by simply applying a voltage to the laser. This is in contrast to slower frequency control techniques which utilize piezoelectric or pump power modulation. The IR emission of the source is converted to the visible using intracavity nonlinear techniques in a design which avoids instabilities from nonlinear mixing. The anticipated performance of the system results in a source with a frequency stability of better than 2 MHz, with a fast linewidth of 10 KHz, thus making it ideal for precision instrument calibration. This microlaser technology offers the potential for extremely frequency-stable, compact, low cost, oscillators in the visible and IR region. The unique technology represents a substantial improvement over current state-of-the-art nonplanar monolithic lasers. For the absolute long term stability requirements of U-AVLIS, the electro-optic microlaser can be referenced to a molecular absorption cell or crystal oscillator. The Phase I project includes a series of risk reduction experiments designed to generate narrow linewidth, frequency stable, visible microlasers. Phase I will develop a diode pumped visible source in a monolithic package. Characterization of the source will lead to a design and implementation of a closed-loop frequency control system referenced to an ultra-stable cavity.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful demonstration of the proposed microlaser will lead to the development of compact, inexpensive sources with potential applications including operation as sources for high bandwidth fiber optic communications links, local oscillator sources for coherent heterodyne detection systems, stable single frequency injection seeders for master/slave oscillator systems, and tunable narrowband sources for precision spectroscopy.

163

An Absolute Diode Laser Wavelength Standard--Optra, Inc., 461 Boston Street, Topsfield, MA 01983; (508) 887-6600
Dr. Michael Hercher, Principal Investigator
Mr. James R. Engel, Business Official
DOE Grant No. DE-FG02-93ER81616
Amount: $74,008

Phase I consists of a research and development program to demonstrate the feasibility of stabilizing the frequency of an inexpensive diode laser to within 1 MHz of the center of an atomic absorption line. A key to the approach will be the use of a frequency discriminator based on the zero-crossing of the anomalous dispersion curve at center line. This will allow active stabilization of the laser frequency without the usual need to dither its frequency. The zero-crossing will be sensed using a stable interferometer and a unique triphase detection technique which is unaffected by laser intensity fluctuations. If successful, the technique can be used with virtually any laser and promises to reduce the cost of laser frequency stabilization, and to simplify the process and minimize the power consumption. Frequency-stabilized laser diodes, because of their inherently low cost, high efficiency, and wide tuning range, are ideal light sources for these applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: An absolute wavelength stabilized source of moderate power is attractive as a source for metrology in such commercial processes as high resolution lithography and diamond turning of optics. It can also serve as a convenient source for calibrating settings of diffraction gratings and other wavelength defining elements. Research applications are in the area of high resolution spectroscopy and for studying laser cooling of atoms.

164

Diffractive Phase Plates and Micro-optics for Beam Diagnostics and Control--Rochester Photonics Corporation, 330 Clay Road, Rochester, NY 14623; (716) 272-3010
Dr. C. Gary Blough, Principal Investigator
Dr. Dean Faklis, Business Official
DOE Grant No. DE-FG02-93ER81544
Amount: $74,973

For the planned research and development effort, several new application areas have been defined that can benefit the uranium-atomic vapor laser isotope separation (U-AVLIS) program. These applications make use of diffractive optical elements for anamorphic beam transformations and microoptics functions that include agile beam steering. In particular, Phase I will design and develop diffractive anamorphic optical systems for shaping high power laser beams to match pump beam and dye beam requirements and generalized aperture requirements. The systems can be designed using conventional lens design codes in combination with an iterative procedure. In conjunction with U-AVLIS researchers candidate parameters for the beam shaping elements including positions in the beam train will be determined. Also, the ability to correct deterministic beam errors in a retrofit package can be very beneficial. Packages that involve arrays of precision microoptical elements will also be investigated. By using direct-write methods for fabricating surface-relief diffractive optics, unique beam shaping functions can be implemented that would be extremely difficult or impossible to realize by holographic methods. The two-dimensional designs will be analyzed under conditions imposed by the mission. Direct-write, surface-relief diffractive elements offer the potential for new advances in modular laser optics. For example, several diagnostic tasks may be performed simultaneously to provide a feedback process where the beam parameters are tightly controlled.

Anticipated Results / Potential Commercial Applications as described by the awardee: High-performance laser optics based on this project can aid the commercialization of laser isotope separation processes. This research has additional applications that include the use of large arrays of aspheric microlenses for imaging and beam steering and diffractive anamorphic telescopes.

165

Separation of Uranium-Iron Alloy from the Atomic Vapor Laser Isotope Separation Process into Uranium Hexafluoride and Iron--Sante Fe Alloys, 133 La Senda Road, Los Alamos, NM 87544; (505) 672-3603
Dr. Guy R. B. Elliott, Principal Investigator
Dr. Guy R. B. Elliott, Business Official
DOE Grant No. DE-FG03-93ER81636
Amount: $75,000

A molten salt process is described for separating the components of the alloy of enriched uranium and iron which is the product of the Atomic Vapor Laser Isotope Separation (AVLIS) process to enrich the ^{235}U content of the parent metal. A simple separation would dissolve the enriched uranium hexafluoride which would be recovered and purified by vaporization from the molten salt. Vaporized and condensed hexafluoride can then be converted by standard technology to enriched uranium oxide which is used as a reactor fuel for commercial nuclear power plants. The separation would enable the removal of the iron powder which would be returned to the AVLIS alloy feed. This feed is formed from iron and natural uranium metal. Phase I will prepare theoretical analyses and experimental plans and perform preliminary experiments which will lead, in Phase II, to proving the concept and developing bench scale equipment.

Anticipated Results / Potential Commercial Applications as described by the awardee: In eight years enriched uranium fuel for U.S. nuclear reactors will be produced by AVLIS. The AVLIS product must be purified to a uranium compound which is used to make the fuel. This project offers the purification technique needed for fuel preparation. Phase I will prepare for process development in later phases.

166

Development of Precision Wavelength Standards for Uranium Atomic Vapor Laser Isotope Separation--Schwartz Electro-Optics, Inc., 45 Winthrop Street, Concord, MA 01742; (508) 371-2299
Dr. James Harrison, Principal Investigator
Dr. Peter F. Moulton, Business Official
DOE Grant No. DE-FG02-93ER81618
Amount: $74,131

Precision wavelength standards in the range 550 to 700 nm are required by DOE for the uranium-atomic vapor isotope separation (U-AVLIS) program. The development of a diode-laser pumped, solid state laser system is planned to meet the program requirements. It involves intracavity sum frequency mixing in a tunable laser (either $Cr{:}LiSrAlF_6$ or $Ti{:}Al_2O_3$), with a second source at 1540 nm. The latter would be a single-frequency InGaAsP device amplified by a diode-laser-pumped, erbium-doped fiber amplifier. The same technology would have immediate application to pollution monitoring systems (currently under development) as well as medical and scientific applications. The immediate goal of Phase I is to evaluate the feasibility of the planned system and to generate a detailed point design for construction in Phase II. Experimental work on the Phase I project includes the construction of a single-frequency $Cr{:}LiSrAlF_6$ ring laser pumped by a pair of InGaAlP diode lasers, and the demonstration of intracavity sum frequency mixing using a $KTiOPO_4$ crystal.

Anticipated Results / Potential Commercial Applications as described by the awardee: In addition to isotope separation, the planned laser system would find immediate application in gas monitoring systems for pollution detection and control. In addition, it would provide a source for clinical applications in medicine and would find use as a scientific laser.

167

A Metallized Pulse Capacitor for the Copper Laser Inverter--Sigma Labs, Inc., 10960 North Stallard Place, Tucson, AZ 85737; (602) 575-8013
Dr. Angelo Yializis, Principal Investigator
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DOE Grant No. DE-FG03-93ER81564
Amount: $75,000

Addressing the need for higher reliability pulse capacitors to serve demanding applications such as the copper laser inverter, a metallized capacitor is planned with a rating of 1-2 microfarads (μF)/2000V, that has superior dV/dt and high frequency current carrying characteristics, and prolonged life at high voltages and high levels of corona discharge. Several innovative improvements have been incorporated in the design that are not found in commercially available parts. A new improved polypropylene film will be used that is produced by a patented process and has unique electrical, thermal, and mechanical properties. This is a hybrid film, composed of capacitor grade polypropylene film and an acrylate polymer coating that has excellent dielectric and self healing properties, and is thermally stable at temperatures in excess of 300°C. The quality of the termination is enhanced and the equivalent series resistance (ESR) is lowered, with the use of a heavy edge electrode that has a resistivity of less than 1.0 ohm/sq cm and an improved spray termination. The equivalent series inductance (ESL) of the capacitor bank will be lowered and the volumetric efficiency increased by assembling several wound rolls into one case and then by replacing the wire leads with a low inductance multi-pin lead frame. The Phase I development work will involve production and metallization of the hybrid film, construction of wound metallized capacitors, and performance evaluation of single capacitor sections under high current and voltage tests. In Phase II the materials and processes will be optimized and low ESR and ESL multisection capacitors will be produced and packaged in a single plastic case. Several 50 µF capacitor banks will be built on printed circuit boards and will be tested, based on the copper laser inverter specifications and on additional accelerated life tests, to establish longer term performance characteristics.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful completion of this project will significantly advance the state of the art in metallized pulse capacitors. The new capacitors will handle higher peak and root mean sqaure currents and their cost will be in line with commercially available products. When applied to the copper laser inverter, the new capacitors will elevate the level of the system reliability and will increase the volumetric efficiency of the 50µF capacitor bank. Other applications include short pulse radar modulators, commercial switching power supplies, commutation, and lighting applications.

168

A Diode Laser Frequency Standard Using Velocity Modulation--Southwest Sciences, Inc.,
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Dr. David Christian Hovde, Principal Investigator
Dr. Alan C. Stanton, Business Official
DOE Grant No. DE-FG03-93ER81541
Amount: $75,000

This project will develop a frequency standard for the uranium-atomic vapor laser isotope separation (U-AVLIS) process using a visible diode laser locked to an atomic resonance. A key feature is the use of the velocity modulation method to provide a high signal/noise locking discriminant without the need to modulate the laser, and with the high powers for sub-Doppler effects. Phase I will produce xenon ions in an alternating current glow discharge tube operated at reduced pressure to produce a positive column region about one half meter long. The electric field in this part of the discharge accelerates the ions, causing a small Doppler modulation of their absorption frequencies. A portion of the diode laser beam is directed down the bore of the discharge, then detected with a photodiode. The photocurrent is amplified and demodulated at the discharge frequency, producing a derivative lineshape that will be used to line lock the laser by electronic feedback. The effects of plasma temperature, pressure, and composition on the demodulated signal/noise ratio and center frequency will be examined.

Anticipated Results / Potential Commercial Applications as described by the awardee: A class of frequency standards in the visible and near infrared based on ion absorption resonances should be developed for the AVLIS program, as laboratory standards, and for coherent optical communications such as frequency shift keying. By using diode lasers and fiber optics, these devices can be made compact, reliable, and maintenance free. Argon and krypton ion lasers also can be stabilized by this method, with applications in holography and Fourier transform Raman spectroscopy.

APPENDIX A

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(609) 259-0501

Praxis Engineers, Inc. ***43***
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Milpitas, CA 95035
(408) 945-4282

PSI Technology Company ***13***
Dr. Anthony A. Pirri, Business Official
20 New England Business Center
Andover, MA 01810
(508) 689-0003

PXL, Inc. ***146***
Dr. Ada Suckewer, Business Official
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Monmouth Junction, NJ 08852
(908) 329-0505

Q-Chem, Inc. ***105***
Dr. Carlos A. Gonzalez, Business Official
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Pittsburgh, PA 15221
(412) 268-6541

Quantum Magnetics, Inc. ***126***
Dr. Lowell J. Burnett, Business Official
11578 Sorrento Valley Road
San Diego, CA 92121
(619) 481-4015

Quest Integrated, Inc. ***159***
Ms. Diana J. Suzuki, Business Official
21414 68th Avenue South
Kent, WA 98032
(206) 872-9500

Radiation Monitoring Devices, Inc. ***151***
Dr. Gerald Entine, Business Official
44 Hunt Street
Watertown, MA 02172
(617) 926-1167

Radix Systems, Inc. ***90***
Mr. Mark R. Ciavardoni, Business Official
6 Taft Court
Rockville, MD 20850
(301) 309-6306

RD Instruments ***73***
Mr. Francis Rowe, Business Official
9855 Businesspark Avenue
San Diego, CA 92131
(619) 693-1178

REB Research and Consulting ***97***
Dr. Robert E. Buxbaum, Business Official
811 Oak Street
East Lansing, MI 48823
(517) 332-0243

Reaction Engineering International ***22***
Dr. Michael P. Heap, Business Official
44 West 300 South, Suite 2306S
Salt Lake City, UT 84101
(801) 328-2002

Rochester Photonics Corporation . . . ***164***
Dr. Dean Faklis, Business Official
330 Clay Road
Rochester, NY 14623
(716) 272-3010

Rocky Research ***46***
Dr. Uwe Rockenfeller, Business Official
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P.O. Box 61800
Boulder City, NV 89006-1800
(702) 293-0851

Ross Computational Resources 62
Ms. Ruth A. Ross, Business Official
318 North Franklin Avenue
Madison, WI 53705
(608) 238-8949

Sage Corporation 58
Mr. John E. Van Dine, Business Official
P.O. Box 278
Piscataway, NJ 08855
(908) 932-3300

Santa Fe Alloys 165
Dr. Guy R. B. Elliott, Business Official
133 La Senda Road
Los Alamos, NM 87544
(505) 672-3603

Schwartz Electro-Optics, Inc. 166
Dr. Peter F. Moulton, Business Official
45 Winthrop Street
Concord, MA 01742
(508) 371-2299

Science Research
Laboratory, Inc. 147, 153
Dr. Jonah Jacob, Business Official
15 Ward Street
Somerville, MA 02143
(617) 547-1122

Sigma Labs, Inc. 167
Dr. Angelo Yializis, Business Official
10960 North Stallard Place
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Soane Technologies, Inc. 69
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Hayward, CA 94545
(510) 293-1850

Solar Car Corporation 47
Dr. Robert A. Adams, Business Official
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Melbourne, FL 32904
(407) 254-2997

Sorbent Technologies Corporation . . . 14
Mr. Sidney G. Nelson, Business Official
1935 East Aurora Road
Twinsburg, OH 44087
(216) 425-2354

Southwest Sciences, Inc. 168
Dr. Alan C. Stanton, Business Official
1570 Pacheco Street, Suite E-11
Santa Fe, NM 87501
(505) 984-1322

Space Exploration
Associates, Inc. 154
Mr. Max L. Lake, Business Official
141 West Xenia Avenue
P.O. Box 579
Cedarville, OH 45314
(513) 766-2050

Spinheat Limited 23
Mr. Michael J. Virr, Business Official
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(203) 254-0340

Spire Corporation 86, 119, 155
Mr. Patrick N. McDonnell, Business Official
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Bedford, MA 01730-2396
(617) 275-6000

Statistical Sciences, Inc. 63
Mr. Matthew Schiltz, Business Official
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Seattle, WA 98109
(206) 283-8802

Structured Materials
Industries, Inc. 32
Ms. D. Rechtleben, Business Official
Enterprise Development Center
240 Martin Luther King Boulevard
Newark, NJ 07102
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Supercon, Inc. **. *107, 138***
Ms. Elaine Drew, Business Official
830 Boston Turnpike
Shrewsbury, MA 01545
(508) 842-0174

Surmet Corporation **. *139, 140***
Dr. Suri A. Sastri, Business Official
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Burlington, MA 01803
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TDA Research, Inc. **. *98***
Mr. Michael E. Karpuk, Business Official
12345 West 52nd Avenue
Wheat Ridge, CO 80033
(303) 422-7819

Thermacore, Inc. **. *141, 156***
Mr. Richard W. Longsderff, Business Official
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Ultramet **. *87***
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Umpqua Research Company **. *74***
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Myrtle Creek, OR 97457
(503) 863-7770

United Solar Technologies, Inc. **. *157***
Mr. Richard J. Kelley, Business Official
522 Dover Point, NE
Olympia, WA 98506
(206) 705-2000

Videodiscovery, Inc. **. *64***
Dr. D. Joseph Clark, Business Official
1700 Westlake Avenue North, Suite 600
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VirTek **. *15***
Mr. Leon Altschul, Business Official
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(508) 635-9905

Vortec Corporation **. *16***
Dr. James G. Hnat, Business Official
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Collegeville, PA 19426
(215) 489-2255

W.W. Gaertner Research, Inc. **. *65***
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Norwalk, CT 06854
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APPENDIX B

State Listing of Awardees

Alabama	137
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APPENDIX C

Proposal Submissions and Awards Listed by States, Territories, and Possessions

State	Number Submitted	Number Selected	State	Number Submitted	Number Selected
Alabama	32	1	Montana	11	1
Alaska	1	0	Nebraska	2	0
Arizona	40	3	Nevada	5	1
Arkansas	11	2	New Hampshire	25	6
California	362	31	New Jersey	69	7
Colorado	126	14	New Mexico	53	3
Connecticut	102	19	New York	85	7
Delaware	4	1	North Carolina	11	1
District of Columbia	4	0	North Dakota	4	0
Florida	39	3	Ohio	71	3
Georgia	21	0	Oklahoma	27	1
Hawaii	1	0	Oregon	20	4
Idaho	9	0	Pennsylvania	77	7
Illinois	51	1	Puerto Rico	2	0
Indiana	6	0	Rhode Island	1	0
Iowa	12	0	South Carolina	3	0
Kansas	3	0	South Dakota	2	0
Kentucky	6	0	Tennessee	29	3
Louisiana	19	0	Texas	88	2
Maine	7	0	Utah	48	1
Maryland	65	4	Vermont	3	0
Massachusetts	236	34	Virginia	73	1
Michigan	28	1	Washington	55	5
Minnesota	20	0	West Virginia	4	0
Mississippi	1	0	Wisconsin	12	1
Missouri	9	0	Wyoming	4	0

Although eligible in each case to participate, there were no submissions from the Virgin Islands, the Commonwealth of the Northern Mariana Islands, or the Trust Territory of the Pacific Islands.

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SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM
(PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0504)

U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585
March 4, 1993

SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0504)

As a former chairman of the SBIR Application Score Verification Panel that had been appointed to evaluate Phase II grant applications for the SBIR program, I am familiar with the Panel's evaluation procedures and its methodology. I believe that the Panel has proceeded in accordance with applicable laws and regulations, that the evaluation was thorough and equitable, and that the information presented formed a sound basis for selection. This statement describes the procurement and sets forth my selection decision.

Procurement Description

The Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564), requires that each Federal agency with an extramural research or research and development budget exceeding $100 million establish an SBIR program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies over the 18 years of the program are as follows:

Fiscal Year	SBIR Set Aside (%)
1983	0.2
1984	0.6
1985	1.0
1986-1992	1.25
1993-1994	1.5
1995-1996	2.0
1997-2000	2.5

Public Law 97-219 also prescribes that the SBIR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the SBIR program. This phase will have a period of performance which is typically six months in duration. Awards during this phase will be up to $50,000. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $500,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-SBIR funded Federal contracts for products or services intended for use by the U.S. Government.

On October 30, 1991, the Department of Energy (DOE) issued its tenth annual program solicitation for Phase I SBIR grant applications. We received 1534 applications in response to that solicitation; and on May 22, 1992, we selected 202 applications for Phase I funding, of which 198 proceeded to grants on July 27, 1992.

The Phase II SBIR program competition is limited to successful Phase I awardees. Under DOE procedures, grant applications for Phase II could be submitted at any time when it was deemed that sufficient progress had been attained under Phase I to justify the effort to be proposed for further development under Phase II. Applicants who wanted to maintain project funding continuity from Phase I to Phase II were asked by DOE to submit their applications not later than December 23, 1992, whereas the submission deadline for proposers not seeking to preserve project continuity is March 26, 1993. Based on the 198 Phase I awards, 60 Phase II applications were submitted by the December 23, 1992, deadline. Our current selections were to be made from these submittals. After March 26, 1993, another selection will be made from Phase II applications submitted by Phase I awardees who choose to submit by March 26 based on the remaining 138 Phase I awards, and from Phase II applications that have already been received but not yet selected for funding.

Selection Criteria

Selections for Phase II awards were made on scientific and technical merit based upon the criteria listed below. Criterion 1 is given twice the weight of each of the other criteria. The five criteria are as follows:

1. The scientific/technical quality of the proposed research or R&D with special emphasis on its degree of innovation.

2. The qualifications of the Principal Investigator and other key personnel to carry out the proposed work and the level of adequacy of available or obtainable instrumentation and facilities.

3. The anticipated benefits, technical and/or economic, of the proposed research, with special emphasis on the likelihood that the project will attract further funding for product or process development after the SBIR support expires.

4. The degree to which the Phase I objectives were met at the time of Phase II grant application submission.

5. The soundness and level of adequacy of the Phase II proposed work plan to meet the problem or opportunity.

All Phase II applications received were subjected to a detailed technical evaluation by experts, both inside and outside the Government. Final decisions were made by DOE based upon the scientific and technical evaluations. In all applications selected for awards, it was demonstrated that a minimum of one-half of the funded research or analytical effort would be performed by the applicant organization.

Selection Rationale

A Technical Project Manager (TPM) was appointed for each of the Phase I projects resulting from successful Phase I applications. Expert reviewers including DOE Laboratory personnel, university professors, and private industry personnel were selected with the help of the TPM, and they evaluated applications against the assigned criteria. The TPM then scored applications based on these reviews. An SBIR Application Score Verification Panel consisting of DOE staff and other technical personnel was established to ensure relative uniformity of scoring across the board on Phase II applications and to assure that scores were based predominantly on meaningful technical reviews. The Panel was also chartered to ensure that there was consistency of scoring both within and between topics. Finally, the Panel was asked to rank the 60 Phase II applications submitted according to the technical evaluations.

I have looked at the evaluation documentation presented by the TPMs. I have also carefully reviewed the recommendations and rankings of the SBIR Application Score Verification Panel and have agreed that the evaluations of the reviewers, the scoring of the TPMs, and the recommendations of the Panel provided valid bases upon which to make a selection. Therefore, based on the ranking of the Panel, I have selected 24 applications for negotiation for award. Included in the 24 applications are all those which received the highest possible technical rating. The remainder was selected from among applications that were rated one point below the highest possible technical rating on the basis of (1) the strength of the follow-on funding commitment for continued development, for the present project, (2) the amount of Phase III funding received for previous DOE SBIR Phase II projects, and (3) program balance. It is my view that these applications represent outstanding technical quality and attest to the commitment of the SBIR program to excellence and to the development of high technology in the small business sector.

Selected Applications

Appendix A is a listing of applications selected for negotiation for award.

Appendix B contains the project summary of each application.

Samuel J. Barish

Samuel J. Barish
SBIR Program Manager

Date: 3/4/93

Appendix A

DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH
GRANT APPLICATIONS SELECTED FOR FY 1993 EARLY PHASE II AWARDS

Company	Project Title
Advanced Technology Materials, Inc. 7 Commerce Drive Danbury, CT 06810	A Real-Time X-Ray Detector
Bend Research, Inc. 64550 Research Road Bend, OR 97701-8599	A Novel Energy-Efficient Membrane System for the Recovery of Volatile Organic Contaminants from Industrial Process Gases
DELTA M Corporation 525 Warehouse Road Oak Ridge, TN 37830	A Dual Liquid Level Measurement System for Pyrochemical Processing of Nuclear Fuels
ERC, Inc. 205 Research Park Drive P.O. Box 417 Tullahoma, TN 37388	A Light Metal Fueled Nonequilibrium Plasma Generator
Haimson Research Corporation 4151 Middlefield Road, Suite 102 Palo Alto, CA 94303-4793	A 17 Gigahertz Traveling Wave Relativistic Klystron for High Gradient Accelerators
Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523	Imaging Systems for Biomedical Applications
Industrial Filter and Pump Manufacturing Company 5900 Ogden Avenue Cicero, IL 60650	Durable, Low Cost Ceramic Materials for Use in Hot Gas Filtration Equipment
Integrated Applied Physics, Inc. 261 North San Gabriel Boulevard P.O. Box 70166 Pasadena, CA 91117-7166	Power Conditioning for Efficient, Effective Removal of Nitrogen Oxides, Sulfur Oxides, and Toxic Materials from Effluent Gases
John R. Bayless Company 20325 Seaboard Road Malibu, CA 90265	A High Energy Far-Infrared Source for Collective Thomson Scattering Diagnostics

Lightwave Electronics Corporation 1161 San Antonio Road Mountain View, CA 94043	**An All-Solid-State Laser Source for Production of Polarized Electrons for the Continuous Electron Beam Accelerator Facility (CEBAF)**
LSR Technologies, Inc. 898 Main Street Acton, MA 01720	**An Advanced Liquid Membrane System for Natural Gas Purification**
Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706	Development of a Process to Synthesize Tubular Fullerenes
OMEGA-P, Inc. 2008 Yale Station New Haven, CT 06520	A Harmonic Converter to Produce High-Power 10-30 Gigahertz Microwaves
ORINCON Corporation 9363 Towne Centre Drive San Diego, CA 92121	A Fast Processor of Tokamak Ion Temperatures
Pen Kem, Inc. 341 Adams Street Bedford Hills, NY 10507	Development of a Dielectric Spectroscopy Probe for Charge and Size Analysis of Industrial Slurries
Physical Optics Corporation 20600 Gramercy Place, Suite 103 Torrance, CA 90501	A Compact Optical Crossbar Switch Array for Large-Scale Photonic Networks
Princeton Scientific Instruments, Inc. 7 Deer Park Drive Monmouth Junction, NJ 08852	A Thomson-Scattering Plasma Diagnostic for Materials Testing and Divertor Concept Testing
PSI Technology Company 20 New England Business Center Andover, MA 01810	A Compliance Advisor: Development of Software Tools for Fuel Switching/Blending to Meet SO_2 Regulations at Coal-Fired Power Plants
REMOTEC, Inc. 114 Union Valley Road Oak Ridge, TN 37830	Environmental Hardening of a Mobile-Manipulator Robotic System for Nuclear Environments
SE Systems, Inc. 26203 Production Avenue, Suite 10 Hayward, CA 94545	Eddy-Current Nondestructive Testing Methods for On-Line Detection of Cable Manufacturing Defects

Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545	A Niobium-Tin Multifilamentary Composite Superconductor with Artificial Copper (Bronze) Inclusions
TechnoConcepts, Inc. 2363 Teller Road, Suite 118 Newbury Park, CA 91320	A Gallium Arsenide 16-Bit Sigma-Delta Analog-to-Digital Converter with a 100 Megahertz Conversion Rate
The Lektrox Company 10301 Bellwood Avenue New Port Richey, FL 34654	Improved Control of Pulp and Chip Refining Through Direct Measurement of the Number and Severity of Fiber Impacts
Viscoustech 2836 Ridge Drive Allison Park, PA 15101-2511	A Torsional Rheometer for Measuring the Properties of Coal and Coal-Water Slurries

APPENDIX B

DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH
GRANT APPLICATIONS SELECTED FOR FY 1993 EARLY PHASE II AWARDS

Advanced Technology Materials Inc.
7 Commerce Drive
Danbury, CT 06810

A Real Time X-Ray Detector

In spite of the enormous growth in thin film processes and products, in-situ process monitors for chemical and physical vapor deposition have been limited to the acquisition of basic process conditions such as temperature, pressure, and flow rates. In Phase I, an in-situ x-ray diffraction (XRD) monitor for real time microstructural analysis of chemically vapor deposited metal and metal oxide films was demonstrated. The XRD device, a position sensitive scintillation detector (PSSD), was modified for use in a reactor environment to measure simultaneously critical film parameters including phase composition, degree of crystallinity, texture (preferred orientation), thickness, and residual stress. In contrast to traditional x-ray diffraction systems, the PSSD system is compact, requires no scanning, and, most importantly, has very rapid sampling times. The Phase I experiments were designed to quickly determine the feasibility of in-situ thin film growth monitoring. By limiting deposition temperatures to 550°C, minimal changes to the primary detector components were required. Phase II will demonstrate the viability of the in-situ PSSD system in real world applications. Integration of robust on-line sensors that can measure critical microstructural characteristics will enable thin film manufacturing strategies that incorporate sensors and active feed-back controls into intelligent processing equipment. Intelligent processing of materials will reduce costs and improve quality for a broad spectrum of products ranging from semiconductors to steel.

Anticipated Results/Potential Commercial Applications as described by the awardee: A commercial, in-situ x-ray diffraction device would be applicable to process monitoring, analysis, and control for numerous manufacturing technologies. Major impacts on quality and yield will lead to rapid industry acceptance of this device in thin film coating, metal forming, semi-conductor processing, and non-destructive evaluation (NDE) applications.

Bend Research, Inc.
64550 Research Road
Bend, OR 97701-8599

A Novel Energy-Efficient Membrane System for the Recovery of Volatile Organic Contaminants from Industrial Process Gases

The removal of volatile organic contaminants (VOCs) from industrial process gases constitutes a significant industrial and environmental problem worldwide. Recovery of VOCs is advantageous, both for environmental reasons and for process-efficiency reasons, but conventional technologies (and "first-generation" membrane technologies) for VOC removal have drawbacks that limit their use for this application (e.g., limitations on the percentage of VOCs that can be removed, excessive energy consumption, and inability to withstand exposure to the feed-stream components and harsh operating conditions required.) The overall goal of this project is to develop a membrane-based system for recovering VOCs that avoids the drawbacks of conventional unit processes and first-generation membrane technology. This new membrane-based VOC-recovery system will be applicable to a wide range of VOCs and will be capable of reducing the concentration of VOCs from very high concentrations to the 20-ppm level or below, recovering the VOCs in liquid form for disposal or reuse. In Phase I, system feasibility was demonstrated. Hollow-fiber membranes from new solvent-resistant polymers were successfully developed, incorporated into high-efficiency modules, and tested. The modules effectively reduced the concentration of acetone in nitrogen feed streams from 42,000 ppm to 20 ppm and maintained performance in long-term (350-hour) tests. An economic analysis showed that the planned system offers major cost advantages over competing technologies. The focus of Phase II is to (1) develop hollow-fiber membranes from one or two alternative solvent-resistant polymers, (2) optimize the VOC-selective coatings used on the hollow-fiber membranes, (3) scale up the membrane modules to a size that will allow field tests and pilot tests at a reasonable scale, and (4) design and fabricate a prototype system for use in field tests.

Anticipated Results/Potential Commercial Applications as described by the awardee: The commercial applications for this membrane-based VOC-recovery system are numerous. It will be applicable to a wide range of VOCs and will be capable of reducing VOC levels from very high values down to about 20 ppm or less. The technology would have applications in the chemical-process, petrochemical, and pharmaceutical industries. Initially, the technology would be commercialized for "end of pipe" applications, and later would be integrated into existing processes as a "waste reduction" technology.

DELTA M Corporation
525 Warehouse Road
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A Dual Liquid Level Measurement System for Pyrochemical Processing of Nuclear Fuels

This project addresses the need for a level measurement system for application to the pyroprocessing of nuclear fuel, as required in the Integral Fast Reactor Program at Argonne National Laboratory (ANL). To this end, proof-of-principle tests in Phase I have verified that both single and dual thermal differential sensors can achieve the sensitivity and accuracy demanded by the applications. Phase II will bring the thermal differential level measurement technique from proof-of-principle established in Phase I to validation of the instrument for the pyroprocessing application. This includes definition of specifications for the simultaneous determination of a liquid metal/molten salt interface and a molten salt/gas interface at a temperature of 500°C or higher, in an environment typical of nuclear fuel reprocessing. The thermal-based level measurement system will be simple in concept, relatively low in cost, rugged, easily insertable and removable from the system, safe in operation, and have an accuracy of better than 3.2 mm (0.125 in.). The design of the Phase II system is supported by technology developed at Oak Ridge National Laboratory during the 1970s and early 1980s for out-of-reactor thermal-hydraulic safety and reactor core design instrumentation. The first year of Phase II will include fabrication and evaluation of a second generation dual sensing probe, encompassing design and fabrication of a high temperature test apparatus, fabrication and testing of a digital-based data acquisition and analysis system, and long term testing of the probes and associated electronics to establish probe stability and measurement reproducibility specifications. Based on these results, a probe system will be fabricated, calibrated, and delivered to ANL for demonstration tests. A final design, along with the pertinent documentation, will then be completed. A separate task will investigate additional probe applications using the established technology, to identify major potential markets, define marketing strategies for industrial commercialization, and identify potential Phase III participants.

Anticipated Results/Potential Commercial Applications as described by the awardee: The end result of this project will be the development and delivery to ANL of a high temperature, rugged, reliable, safe, and cost-effective dual liquid level measurement system for pyrochemical processing of nuclear fuels. Potential commercial applications include level measurements of liquid metals and molten salts in the energy and metal production areas, in the chemical industry, at research institutions, and for leak detection in nuclear/chemical waste storage tanks located at various nuclear facilities throughout the United States.

ERC, Inc.
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A Light Metal Fueled Nonequilibrium Plasma Generator

The nonequilibrium plasma generator (NPG) concept burns high energy metals (e.g., aluminum), mixing the metal oxide products with an inert gas stream to produce a plasma capable of sustaining nonequilibrium ionization in a magnetohydrodynamic (MHD) generator. Light metal combustion produces extremely high flame temperature. When inert gas (argon) is mixed with combustion metal oxides and expanded to MHD generator inlet conditions, the metal oxides will condense in minute particles yielding a clean, extremely hot plasma that can drive the nonequilibrium MHD process. The NPG concept can produce a steady state source of higher temperature nonequilibrium plasma than is achievable with current technology, which will stabilize the MHD nonequilibrium ionization process and lend higher efficiency and power density to the MHD disk generator. Phase I included scientific and engineering analyses of NPG, and identified aluminum as the preferred fuel and argon as the best working fluid. Powdered aluminum flow experiments were conducted, and a conceptual design for an aluminum powder feed system was conceived; this system will require developmental testing in Phase II. The principal objective of Phase II is to design, fabricate, and test a laboratory scale

NPG. The experimental NPG will burn fine aluminum powder in pure oxygen and vitiate argon to create an argon plasma. A series of proof-of-principle experiments will be conducted with the NPG test apparatus. The first tests in Phase II will be conducted to determine the operating conditions and NPG geometry required for optimizing the aluminum combustion and argon mixing processes. The concluding tests will demonstrate production of a nonequilibrium plasma with the NPG concept. The experimental program will be used to establish a design data base on the NPG that can be used to scale up the concept to commercial size. Phase II will simultaneously be directed at conceptual study of using the NPG in a pulse power, nonequilibrium MHD disk generator system. This application is chosen for near term development. Other possible applications for the NPG will be explored in Phase II including use of the NPG in closed cycle commercial power MHD power generation. A potential Phase III program will be planned to build a large scale aluminum-argon NPG, integrate it with an existing MHD disk generator, and conduct first-of-a-kind demonstrations of pulse power from a nonequilibrium MHD disk generator system.

Anticipated Results/Potential Commercial Applications as described by the awardee: The light metal NPG will provide a compact device capable of producing a high energy plasma or stream that can be used in MHD research and parallel technologies. It has potential as a product for research and commercial field applications. The NPG can support central power MHD research through replacement of the large regenerative heat exchangers needed for nonequilibrium ionization MHD disk generator experiments. The NPG is a device that could directly drive an MHD disk generator, making this concept viable for pulse power MHD. The NPG concept is applicable to research in other MHD disciplines, e.g., MHD propulsion and in ground tests of gas-cooled nuclear reactor concepts for MHD power or rocket propulsion.

Haimson Research Corporation
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A 17 GHz Traveling Wave Relativistic Klystron for High Gradient Accelerators

Electron accelerator linear collider studies continue to support earlier contentions that the most favorable choice of linac frequency is in the range of 10 to 20 gigahertz (GHz). There are advocates for working at the upper end of this range and with increasing values of beam pulse width, e.g. with pulse widths extending into the steady state regime, so that the charge per bunch and wake field effects can be reduced without loss of luminosity. Considerable interest exists in 17 GHz linear collider technology, and some research activities are in progress at MIT and in private laboratories interested in commercial applications of high frequency linacs. However, there are no practical sources of high radio frequency (RF) power presently available to support 17 GHz high gradient accelerator (HGA) research. (Linear collider RK development is at 14 GHz in Russia, and at 11.4 GHz in the USA and Japan.) Phase I investigated design approaches for the RF source and prepared layout and subassembly drawings for the Phase II high power RF test stand. It is the objective of Phase II to (1) design and fabricate a 17 GHz prototype traveling wave relativistic klystron having a 60 dB gain and an efficiency of > 48%, and (2) conduct high power, long pulse RF tests on this tube using an existing 580 kV, 60 MW video pulse power transmitter having a 1 μs pulse top characteristic ideally suited for demonstrating high quality RF performance. It is a further objective of Phase II to develop and fabricate an evacuated high power rectangular waveguide network comprising special WR62 components for precision measurement and absorption of the klystron output RF power - a necessary prerequisite for a carefully integrated overall test facility suitable for 17 GHz RK and HGA structure research. This 17 GHz prototype RF source, in direct combination with a 60 cm long HGA structure, will be capable of demonstrating electron beam energies in excess of 30 MeV. The long pulse specification of this tube will also make it a strong candidate for a 200 ns linear collider (4x) pulse compression system.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that Phase II will result in a compact, high power RF tube suitable (1) specifically for high gradient accelerator systems, with the capability of demonstrating high resolution beam performance using electron bunch widths of <1 ps, and (2) for commercial applications that would benefit from the substantially reduced size and weight of a 17 GHz linac configuration.

Hypres, Inc.
175 Clearbrook Road
Elmsford, NY 10523

Imaging Systems for Biomedical Applications

Many of the activities of the human body manifest themselves by the presence of a very weak magnetic field outside the body, a field that is so weak that an ultra-sensitive magnetic sensor is needed for specific biomagnetic measurements. Superconducting quantum interference devices (SQUIDs) are extremely sensitive detectors of magnetic flux and have been used extensively to detect the human magnetocardiogram and magnetoencephalogram and other biomagnetic signals. In order to utilize a SQUID as a magnetometer, its transfer characteristics should be linearized. This linearization requires extensive peripheral electronics, thus limiting the number of SQUID magnetometer channels in a practical system. The digital SQUID integrates the processing circuitry on the same cryogenic chip as the SQUID magnetometer and eliminates the sophisticated peripheral electronics. Such a system will be compact and cost effective, and require minimal support electronics. This project will lead to the development of thin-film digital magnetometer/gradiometer chips. Each chip, in addition to having on-chip processing circuitry coupled to a SQUID, will also have an integrated superconducting transformer to facilitate its interface to an external pick-up coil. As a result of this effort, it will be possible to design and fabricate single chips that will contain arrays of digital SQUIDs for integration in a multi-channel SQUID system, thereby reducing the cost and complexity of such systems. The major cost associated with the present SQUID-based biomagnetometer systems is the shielded room environment, which can be as much as $1 million. The digital SQUID significantly relaxes the requirements on the low frequency magnetic field shielding and reduces the shielding cost considerably. Significant cost savings are also realized by eliminating much of the peripheral electronics, thus allowing multi-channel systems to be built very cost effectively. In Phase I, a one-bit digital SQUID magnetometer was designed, simulated, fabricated, and evaluated. The validity of the concept was demonstrated. Phase II will optimize the design of the digital SQUIDs, with feedback circuitry developed during Phase I, using niobium technology. Development activities will lead to the design, fabrication, and evaluation of an optimized multi-bit SQUID chip.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will lead to the development of an all-thin film SQUID chip for use as an ultra-sensitive magnetometer. The chip is a self-contained magnetometer with on-chip processing circuits and will require minimal support electronics. Consequently, arrays of such chips can be realized very cost effectively for integration in multi-channel SQUID magnetometer systems for use in non-invasive biomedical instruments such as multi-channel magnetocardiograms and magnetoencephalograms.

Industrial Filter and Pump Manufacturing Company
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Cicero, IL 60650

Durable, Low Cost Ceramic Materials for Use in Hot Gas Filtration Equipment

Ceramic candle filtration is an attractive technology for particulate removal at high temperature. Due to their simple and cost effective design, temperature capability, and high filtration efficiency, ceramic candles are one of the few clean up technologies which can consistently meet gas turbine manufacturer's inlet particulate requirements and Clean Air Act mandates. Unfortunately, traditional "hard" ceramic candles made from granular silicon carbide, etc., can be prone to failure from physical and thermal shock and chemical attack; also, these candles tend to be expensive and, owing to their weight, present internal filter design problems. Unlike "hard" candles, vacuum formed chopped ceramic fiber (VFCCF) filter candles offer excellent physical and thermal shock resistance at a low cost, using existing vacuum forming technology. The VFCCF "skeleton" can be further treated with colloidal materials to tailor particle retentivity, strength, and corrosion resistance to suit a given application. The products are significantly lighter in weight than their "hard" ceramic counterparts. With their combined strength, high temperature capability, and low thermal expansion, VFCCF materials are ideal for both filter elements and internal filter hardware. Phase I efforts showed that the strength characteristics of VFCCF materials respond extremely well to the infusion of colloidal ceramic oxide solutions. It was possible to increase strength of prototypical VFCCF tubesheet specimens eight-fold. By variation in colloidal solution application techniques and curing methods, it was possible to increase VFCCF filter candle strength in critical flange and end cap areas with a minimal decrease in candle permeability. The Phase II effort will perfect the best colloidal application and treatment methods from Phase I, and evaluate the effects of long term alkali exposure at high temperature on the strength characteristics of the most promising specimens. Additionally, efforts will be made to investigate mullite and Saffil VFCCF filter components, longer fiber lengths, and an integrally formed candle flange.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase II efforts will show how well these treated materials tolerate temperature and vapor-phase alkali species, on a long-term basis. Increased durability, higher temperature capability, and lower installed and replacement costs of these novel materials will promote commercial acceptance of ceramic candle filter technology and increase overall coal utilization process efficiency and reliability.

Integrated Applied Physics, Inc.
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Pasadena, CA 91117-7166

Power Conditioning for Efficient, Effective Removal of Nitrogen Oxides, Sulfur Oxides, and Toxic Materials from Effluent Gases

Pulsed corona discharge, silent discharge, and electron beam processing of effluent gases have been shown to remove effectively a variety of hazardous air pollutants. Recent experiments have demonstrated removal of NO_x and SO_2 from coal burning industrial plants and diesel engines. A key requirement for implementing this process is efficiently and reliably producing high voltage high current pulses with fast risetime and short pulse length at high repetition rates. Ways of producing such pulses have long been known; but since they have been developed for the exacting requirements of radar and particle accelerators, they have been too expensive and delicate to use in industrial gas cleaning applications. Workers have been forced to use old, spark-gap technology in order to obtain the necessary life and ruggedness at reasonable expense. This project will develop a high voltage power modulator for efficiently driving a non-thermal plasma treatment reactor suitable for a demonstration of these processes. The modulator is based on an innovation in switching technology and novel modulator concepts demonstrated in Phase I, and will use a low-cost, high efficiency approach to generating the necessary pulses. This approach will feature both a novel transformer which allows the modulator to produce high current, high voltage pulses with a minimum voltage stress on the switch, and the new back-lighted thyratron-superemissive cathode (BLT-SEC) switch which operates with a superemissive cathode allowing very high currents in a small package with a long lifetime. The switch has demonstrated repetition rates and lifetime an order of magnitude larger than spark gap switches operating at comparable currents. Phase I demonstrated this switch in a novel modulator producing 100 kV output pulses with 80% efficiency using a switch voltage of 25-30 kV. Phase II will produce a modulator giving 100 kV, 10 kA, 200 nsec output pulses with 50 nsec risetime at 300 Hz. The system will have >85% efficiency and a long life. Applications will result in the design of a pilot plant demonstration that could be carried out in Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of this project, demonstrating a significant improvement in pulse modulator efficiency, will result in low cost, reliable pulsed power systems for pulsed plasma treatment of coal burning plant flue gases for efficient emission control. The innovation of the BLT-SEC switch combined with novel modulator techniques will make this approach to emission control economically and technically feasible. The systems developed will have applications other than large electrical and industrial plants, including residential fossil fuel fired systems, and diesel engine emission reduction.

John R. Bayless Company
20325 Seaboard Road
Malibu, CA 90265

A High Energy Far-Infrared Source for Collective Thomson Scattering Diagnostics

A critical need exists for a diagnostic instrument to measure the energy distribution and density of confined energetic ion components in D-T burning fusion tokamaks (e.g. confined alpha-particles with 3.5 MeV birth energy). Collective Thomson Scattering (CTS) is recognized as the most attractive approach for obtaining this information. Based on the analyses performed in Phase I, a CO_2 laser-pumped far-infrared (FIR) laser operating at a wavelength of 152 μm offers the optimum source for this CTS application. This compact, low-cost laser source would be operated in a repetitively pulsed mode (30 Hz) with moderate pulse length (2μs) and energy (~1 J/pulse). High signal-to-noise will be achieved by integrating over ~10 pulses. The advantages of the FIR source are: (1) avoidance of density and plasma absorption/emission limits, and lower cost relative to gyrotrons; (2) much lower cost, size, and complexity relative to free-electron lasers and (3) a larger scattering angle and a lower cost receiver system relative to a 10 μm laser source. A laboratory prototype 152 μm laser system will be developed and demonstrated in Phase II. This laser system will be designed to deliver a minimum of 0.5 J (possibly up to 1 J) in 2 μs pulses at a repetition rate of 30 Hz in 10-pulse bursts. These parameters are adequate to measure the characteristics of the bulk and energetic ions in the Alcator C-MOD tokamak. A highly qualified team, combined with the incorporation of key elements of existing hardware, will help to ensure the success of Phase II. Moderate extensions of the technology that will be demonstrated in Phase II will be very attractive for making CTS measurements in the International Thermonuclear Experimental Reactor (ITER). Thus, the planned effort will provide a new and innovative source that will enable high quality CTS measurements in present experiments and future D-T burning fusion experiments.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will provide an advanced source technology for use in CTS diagnostic systems which will have important applications in Government-sponsored fusion research projects. The proposed FIR laser technology could serve as valuable U.S. contribution to the ITER effort. The high-performance CO_2 pump laser to be developed as part of the FIR laser system will, itself, be useful for CTS at 10 μm. It will also be very attractive for use in long-range DIAL (differential absorption LIDAR (light detection and ranging)) systems for remote chemical sensing and environmental monitoring. These systems are expected to have many important commercial and Government applications.

Lightwave Electronics Corporation
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An All-Solid-State Laser Source for Production of Polarized Electrons for the Continuous Electron Beam Accelerator Facility (CEBAF)

This project addresses the need for a complete diode-pumped, all-solid-state tunable laser system suitable for generating polarized electrons at the Continuous Electron Beam Accelerator Facility (CEBAF). Phase I investigated a number of all-solid-state laser approaches that could be used in a second generation source for CEBAF. This effort has identified a clearly preferred approach: the use of chromium (Cr)-doped laser crystals which can be directly pumped by 670 nanometer (nm) "red" diode lasers. Phase II will pursue detailed development of this approach. The first step will be to develop a 670 nm diode pump module that will combine the output of ten diode lasers to yield a bright pump source with approximately 2 watts of optical power. This source will be used to develop Cr-doped, tunable, mode-locked lasers suitable for generating polarized electrons for CEBAF. High repetition rate mode-locking in the range of 100-1500 megahertz (MHz) will be investigated. The aim is to produce pulsewidths of 10-100 picoseconds and average powers of 100-300 milliwatts. This all-solid-state laser system will be compact, efficient, long-lived, and reliable. These characteristics will make this laser a cost effective, superior replacement for the first generation source to be used at CEBAF.

Anticipated Results/Potential Commercial Applications as described by the awardee: A complete diode-pumped, all-solid-state tunable laser system suitable for generating polarized electrons at CEBAF will be developed. This laser will have many other scientific and industrial applications, such as in seeding high-peak power (terawatt) amplifier systems, spectroscopy, probing of semiconductors, atmospheric monitoring, and evaluation of linear and nonlinear optical materials. No diode-pumped, all-solid-state tunable source is currently commercially available. The 670 nm pump module by itself will also find commercial application as a replacement for small-frame krypton-ion lasers.

LSR Technologies, Inc.
898 Main Street
Acton, MA 01720

An Advanced Liquid Membrane System for Natural Gas Purification

The cost associated with contaminant removal from natural gas is considerable. Impurities such as H_2S, CO_2, N_2, moisture, and natural gas liquids must be removed in order for the gas to be suitable for pipeline transport. H_2S removal and recovery in particular can involve costly processing steps, due to the low selectivity of this contaminant by chemical solvents, which also have an affinity for CO_2. This project will develop a novel Moving Liquid Membrane System (MLMS) for the selective removal of hydrogen sulfide. The MLMS combines absorption and regeneration in the same processing unit. Its design utilizes a large surface area for high mass transfer in a compact control volume. Also, the liquid circulation rate is much lower than that of conventional absorption systems. Phase I has shown that the MLMS has the ability to produce very high H_2S permeability and H_2S/CO_2 selectivity. The bench-scale membrane apparatus has also proven to be completely stable with no evidence of membrane dryout or degradation. The concept needs further refinement of its design through additional laboratory and pilot-scale testing. Phase II will focus on further testing for H_2S removal using simulant feed gases. It is also important that new gas processing technology be brought to the field to validate its operability with real gas. Therefore, a larger pilot scale unit will be constructed to evaluate the long-term operability of the system with industrial gas. A key aspect of the research will be to bring the technology to the demonstration stage.

Anticipated Results/Potential Commercial Applications as described by the awardee: The MLMS is well-suited to treating gases with significant H_2S concentration (up to the percent range), especially when the CO_2 to H_2S concentration ratio is high. Projections from the gas industry indicate that new reserves will likely be smaller, of lower quality, and at remote locations. The simplicity and performance of the MLMS will make it an attractive choice in these applications.

Materials and Electrochemical Research Corporation
7960 South Kolb Road
Tucson, AZ 85706

Development of a Process to Synthesize Tubular Fullerenes

The demonstration that fullerenes (buckyballs) can be produced from a carbon arc has opened a complete new field of science which includes producing nanoscale tubes (buckytubes) that are another facet of carbon's synthetic engineering potential. Buckytubes have been reported by two other groups, but the Phase I program developed processing that achieved substantially higher yields (80%) and tube lengths over three times as long (10μ), as well as a variety of polyhedral structures. The Phase II program plans to optimize the processing to produce further improved buckytubes, optimize the harvesting of the pyrolytic deposit containing the tubes, optimize the fractionating/separating of the tubes from polyhedral shapes and graphite particles, fully characterize the mechanical and electrical properties of the tubes, and produce tubes with preferred mechanical or electrical properties. Activities will be conducted to permit scale-up demonstration and repeatability of optimization processing to synthesize and harvest buckytubes in high quality clean form for application development, and to provide economic estimates for large scale production. Concurrently, fundamental investigations will be conducted to (1) demonstrate doping tubes, (2) establish the mechanism of tube formation, (3) establish reactive properties compared to buckyballs, and (4) determine feasibility of producing very long/continuous tubes. The Arizona Fullerenes Consortium of Universities will provide characterization support and consultation on mechanisms. This program will maintain the U.S. technology lead in fullerene technologies and provide the technology/basis for large scale production of buckytubes.

Anticipated Results/Potential Commercial Applications as described by the awardee: Buckytubes that have molecular dimensions will be produced in controlled diameters and lengths with l/d > 1000 and are expected to have excellent mechanical and electrical properties. The applications will be similar to those for buckyballs, and there may be further applications as reinforcements in all types of matrices, conductors and possibly superconductors.

Omega-P, Inc.
2008 Yale Station
New Haven, CT 06520

A Harmonic Converter to Produce High-Power 10-30 Gigahertz Microwaves

This project addresses the need for new radiofrequency (RF) sources for the next generation electron-positron collider. In Phase I, theory and computation indicated that the fifth harmonic conversion efficiency can be over 50%, and that most of the residual beam energy can be recovered in a one-stage depressed collector. Candidate designs for demonstration proof-of-principle experiments were also selected based on the use of an available 20 megawatt, 2.85 gigahertz (GHz) klystron source. In Phase II, experiments are planned to assess the theoretical predictions of low power flow into competing modes, and of the weak influence of the expected levels of spread in beam particle guiding center and axial momentum. Means of increasing the direct conversion efficiency will be explored. Theory for the acceleration and conversion processes will be extended to account for beam space charge and for harmonic conversion in grooved waveguides. This will demonstrate the harmonic conversion from spatiotemporal modulation on an electron beam produced by cyclotron autoresonance acceleration.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful demonstration of efficient, high-power harmonic conversion in the range of 10-30 GHz would provide an economically appealing source of microwaves to drive a teravolt(TeV)-level electron-positron collider, since use would be made of existing SLAC klystrons and supporting systems. Other potential uses of efficient high-power harmonic converters include heating and control of plasmas for fusion energy, millimeter wave radars, and applications in deep space communications.

ORINCON Corporation
9363 Towne Centre Drive
San Diego, CA 92121

A Fast Processor of Tokamak Ion Temperatures

Charge Exchange Recombination (CER) spectra provide an important measurement of ion temperatures in tokamak experiments, but availability of results has been severely impacted by the analytical computation time. Phase I has demonstrated that it is feasible to estimate tokamak ion temperatures and Doppler shifts with a neural network. This demonstration was performed with a large database of actual CER spectra supplied by the DIII-D project at General Atomics. The parameter estimation process is a straightforward application of neural net learning techniques, using the rigorous analytical best-fit results as the "truth," or training target. A three-layer perceptron was the network configuration used in this study; best results were achieved with hidden layers of 25 nodes each. The error between the output parameters determined by the net and the target truth values was found to be of comparable size to the uncertainty of the truth values. Some of the uncertainty values are in fact quite large, and a further reduction of network output errors may be possible by accounting for the uncertainty when training. The objective of Phase II is to produce an operational system that can accept the stream of CER spectral data, process the data with the neural network of Phase I, and output 8000 ion temperature and Doppler shift estimates within two minutes after the data are available. The planned approach is to configure a dedicated microprocessor system, similar to those employed in other signal processing applications, to meet the present requirements. The planned system is formed from modular hardware in a VME chassis and a mix of pre-existing neural net and new, application-specific software. Detailed analysis is given for the time required for each step in the data transfer and processing chain, using the known performance rates of specified hardware. The system design is cost-effective and meets the processing time requirement with a safety margin of ten. The task breakdown, costing, and schedule indicate that a program in which a programmable real time information image signal processing multichannel (PRISM)-based fast processor will be operational in the second year of the project is achievable.

Anticipated Results/Potential Commercial Applications as described by the awardee: The principal result will be the solution of the CER processing bottleneck problem by virtue of the operational system providing 8000 temperature and shift estimates per discharge. The operational system will represent transfer of defense-agency supported technology. It is expected that similar processors will be applied to CER and other diagnostics at fusion research centers worldwide. The planned system is a major step toward real-time processing of kinetic parameters, necessary for feedback control in the International Thermonuclear Experimental Reactor.

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Pen Kem, Inc.
341 Adams Street
Bedford Hills, NY 10507

Development of a Dielectric Spectroscopy Probe for Charge and Size Analysis of Industrial Slurries

The focus of this project is on the design of a small and robust remote sensor probe to characterize the charge and size of colloidal dispersions (suspensions and emulsions). Such dispersions might have high particle concentration with submicron sized particles and would therefore be unsuitable for optical methods. Many dispersions of interest also have particles with low density contrast, which make them unsuitable for ultrasonic analysis. The planned approach combines rapid measurements of dielectric spectra of the colloid with a deconvolution of the measured spectra to obtain size distribution and charge. The innovation comes from combining expertise in the design of signal processing for colloid instruments (involving electrophoresis and vibration potential) to obtain zeta potentials, with expertise in deconvolution of ultrasound and Fourier transform-infrared (FT-IR) spectra to obtain particle size distributions. In Phase I, a microsensor was designed and fabricated, and research was carried out leading to a proof of concept, based on testing with several colloid systems. During Phase II, the probe design will be improved and extended, and new deconvolution algorithms will be developed using the real and imaginary parts of the measured spectra. Some advances in current theoretical understanding of underlying polarization phenomena are needed to address many dispersions of practical interest, for example, accounting for the effects of high particle concentrations. These will be addressed in Phase II. Tests will be performed using both model and industrial colloids to evaluate the performance of the new micro sensor probes, new theoretical relationships, and new deconvolution algorithms.

Anticipated Results/Potential Commercial Applications as described by the awardee: Potential uses of the planned remote sensor probe for dielectric spectroscopy include charge and size characterization of many colloidal dispersions encountered in energy production and/or conservation, involving petroleum, coal, and food, as well as biomedical industries. The sensor is expected to be small and rugged. It can be used like a pH probe or it can be surface-mounted in on-line applications. Examples of applications with recognized energy savings potential include processing of industrial emulsions, heavy crudes, tar sands, food products, and several organic or inorganic pigments.

Physical Optics Corporation
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Torrance, CA 90501

A Compact Optical Crossbar Switch Array for Large-Scale Photonic Networks

The large amounts of data generated in high energy physics experiments make necessary data acquisition systems or interconnect networks capable of handling very high data rates and large scale data switching. A novel optical crossbar switching technique for large scale data switching functions and high data communication bandwidth operations offers promise in these applications. In addition to compact size, light weight, and immunity to electromagnetic interference, the planned optical crossbar switching technique also has other unique characteristics, not simultaneously satisfied by any other optical crossbar switching technique. In Phase I, a preliminary design of the crossbar switching elements was completed, the feasibility of the planned optical switching concept was experimentally demonstrated, an array of switches was constructed, and the characteristics of the crossbar switch were estimated. The limitations of the optical switching concept in scaling up the array were also explored. Phase II will concentrate on product development of optical crossbar devices for both high energy physics experiments at DOE laboratories and various commercial photonic interconnect applications. The primary goal of the Phase II project is to develop working, large-scale optical crossbar switching arrays (>32 x 32; ideally 64 x 64) capable of high data transmission rate, high switching speed, and very low crosstalk. To achieve this goal, a system prototype demonstration, utilizing existing electronic systems for data sources and destinations, and optoelectronic transceiver boards as the interface between the digital electronics and optical components/devices will be constructed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The large-scale optical crossbar switching arrays developed in this project can be immediately applied to high energy physics experiments at DOE laboratories, and can also provide a new family of products for commercial uses, such as in computer-to-computer networks, local area networks, and multiprocessor interconnect networks.

Princeton Scientific Instruments, Inc.
7 Deer Park Drive
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A Thomson Scattering Plasma Diagnostic for Materials Testing and Divertor Concept Testing

The next generation of magnetic confinement fusion research machines, such as the International Thermonuclear Experimental Reactor (ITER), will impose extraordinary demands on the first wall materials in the vacuum vessel and especially the divertors. Phase I has resulted in the conceptual design of a Thomson scattering based plasma diagnostic suitable for measuring the plasma characteristics near boundary surfaces. Such diagnostic measurements are necessary in interpreting the results from testing candidate first wall/divertor materials and divertor operating scenarios for the next generation of magnetic confinement fusion machines. This design is also a candidate for possible feedback control of divertor plasma conditions. The compact design resulting from Phase I should have much broader applications as well. It is suitable as a general Thomson scattering diagnostic for many small plasma devices, and for measurements in otherwise inaccessible regions of larger plasma devices, such as scrape-off plasmas and edge plasma measurements. In Phase II a prototype of the Thomson scattering diagnostic will be designed and built, and made available for use on plasma generator test facilities for materials research and fusion research.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase II will result in the design, construction, and test of a new Thomson scattering plasma diagnostic instrument. The primary commercial application for the planned Thomson scattering instrumentation will be in plasma research, and there is an international market for such systems in fusion and other plasma research such as toxic waste disposal. This system may also be of particular interest as a general Thomson scattering diagnostic for university-scale plasma devices.

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20 New England Business Center
Andover, MA 01810

A Compliance Advisor: Development of Software Tools for Fuel Switching/Blending to Meet SO_2 Regulations at Coal-Fired Power Plants

This project will develop a protocol and model for fuel switching/blending to meet SO_2 regulations at coal-fired power plants. Utilities are adopting coal switching and blending in order to meet more stringent SO_2 emissions regulations. However, most utility companies lack experience in burning "non-design" coals, and are in need of guidelines to help them assess the impact of different coals and blends on the performance of their boilers. The model will allow utilities to select and blend coals which meet SO_2 regulations while minimizing boiler operational problems such as deposition or increased opacity. The model will reveal rational blending strategies by considering: (1) the beneficial effects of flyash capturing SO_2, and (2) the detrimental effects of flyash causing operational problems such as slagging and poor electrostatic precipitator (ESP) performance. The software product is based on the successful results obtained from Phase I as well as the grantee's experience in boiler slagging. Through systematic experimental studies in Phase I, it was found that significant in-situ capture of SO_2 is possible with calcium in coals and coal blends. The grantee has developed a model that can predict the SO_2 reductions from knowledge of ash chemical composition. In Phase II, there will be further study on the impact of coal switching and blending on the performance of existing boilers, development of rules for evaluating the performances of coals and coal blends, and assessment of the impact of in-situ sulfur capture by ash on slagging and ESP performance. The technical approach will include laboratory experiments to develop submodels for sulfation and SO_3 formation, incorporation of existing slagging and ESP submodels, and selected field testing to validate the overall model. Also, these models will be combined with PC-based, user-friendly slagging models developed previously to produce the end commercial product, a PC-based tool to evaluate SO_2 capture by ash and its impact on slagging and ESP performance.

Anticipated Results/Potential Commercial Applications as described by the awardee: The software product will be able to predict quantitatively the SO_2 emission levels of given coals and the deposition potential of blends. The software will provide to electric utilities a tool for intelligent selection and blending strategies. This will allow relatively inexpensive coals to be utilized, while meeting the SO_2 regulations and minimizing operational problems.

REMOTEC, Inc.
114 Union Valley Road
Oak Ridge, TN 37830

Environmental Hardening of a Mobile-Manipulator Robotic System for Nuclear Environments

This project will involve testing and design to environmentally harden a commercially available mobile robot. In Phase I, the active components of this robot were classified, and the expected total-dose hardness of each component was estimated. Component manufacturers were contacted to determine whether radiation hardness and temperature data were available for each component. This baseline of information was used to prioritize the testing of components and replacement item identification. The initial evaluation has indicated that the Phase II objective of a megarad hardened control system should be achievable. The most critical components, for which there were no historical data, were selected for early baseline testing. Components will be evaluated for stability in harsh environmental conditions, and corrective action will be taken to replace or protect susceptible items. By using available off-the-shelf replacements to the maximum extent possible, the system costs will be kept to a minimum. The primary focal point of the project is the computerized control system of the robot. The microprocessor, along with associated circuitry, relays, amplifiers, etc. present the most difficult challenges in environmentally hardening. In Phase II, the design of the entire robot will be evaluated, and hardened components will be used in place of identified weak items. Module-hardened control components will be tested and modified if necessary. The robot will be assembled from components, and cold-tested. The entire vehicle will be tested in an in-irradiation environmental chamber at the University of Florida. This effort will provide nuclear facilities with substantially improved capabilities to perform tasks in these harsh environments.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will culminate in the availability of a commercially available radiation hardened mobile robot. It will provide operators of nuclear facilities with a vehicle to perform routine and accidental functions in areas inaccessible to personnel. Additionally, specific components, i.e., computerized control systems, will be adaptable to other remote equipment such as bridge cranes, master-slave manipulators, and hot cell process equipment.

SE Systems, Inc.
26203 Production Avenue, Suite 10
Hayward, CA 94545

Eddy-Current Nondestructive Testing Methods for On-Line Detection of Cable Manufacturing Defects

The overall objective of Phase I was to demonstrate the feasibility of using eddy-current technology for detecting manufacturing defects in superconducting cable, in a production environment. It was demonstrated in Phase I that eddy-current data from a single probe excited at 1 megahertz (MHz) and at 2.2 MHz can be used to detect all defects of importance on one narrow side. The objective of Phase II is to develop and demonstrate a prototype system capable of automatically inspecting superconducting cable as it is produced to detect broken and missing wire, cross-overs, sharp corners, and cold welds on both the narrow sides and the wide sides. Eddy-current probe assemblies, cable support fixtures, and test procedures will be developed for and demonstrated on 50 mm inner, 50 mm outer, and 40 mm outer superconducting cable. Phase II will utilize a state-of-the-art, commercial eddy-current instrument, smartEDDY 3.0, with custom designed probes, cable fixturing, and specially modified software. The smartEDDY 3.0 instrument has unique real-time digital data processing capabilities, data storage capabilities, and operating interfaces which make it ideally suited for this application. During a production run, the system will automatically store a defect report. The report will contain the production run ID number, the defect sequence number, the defect type, the defect location in centimeters from the beginning of the run, and the related eddy-current signal file name. Four surface probes and up to four instrument modules will be used. Two probes will be directed at inspection of the narrow sides of the cable, and two probes will be directed at the wide sides of the cable. The wide side probes will contain up to four sensing elements each to achieve 100% coverage.

Anticipated Results/Potential Commercial Applications as described by the awardee: Full commercialization of the inspection system will be done in Phase III. Inspection systems will be installed on production lines which manufacture cable for the Superconducting Super Collider (SSC). The SSC will require 13 production cabling machines, each with an inspection system. Additionally, magnet vendors may be required to perform acceptance testing on cable received from cable manufacturers. This would increase the number of inspection systems required by ten, for a total of 23.

Supercon, Inc.
830 Boston Turnpike
Shrewsbury, MA 01545

A Niobium-Tin Multifilamentary Composite Superconductor with Artificial Copper (Bronze) Inclusions

The purpose of this project is to develop a new type of low-cost niobium-tin (Nb_3Sn) multifilamentary superconducting wire using copper (Cu) (bronze) as the artificial flux pinning centers to enhance critical current densities of the conductor in intermediate and high magnetic fields. Very high non-Cu critical current densities of greater than 1900 and 1000 A/mm^2 at fields of 9 and 12.5 tesla, respectively, were achieved in the internal-tin type of conductor samples prepared in Phase I using a jelly-roll technique. There is evidence that the Cu inclusions artificially introduced into the A-15 matrix increase the critical current densities in A-15 layers about 15%, compared with the sample without Cu inclusions in filaments. Phase II will continue work on optimization of the amount of Cu in filaments, Cu-to-Cu spacing, filament size, processing and heat-treatment parameters, in order to further increase the current-carrying capability of the conductor at magnetic fields greater than 10 tesla. The most promising conductor will be scaled up in size and quantity, aiming for fusion applications such as the International Thermonuclear Experimental Reactor (ITER), by using a double-restacking technical approach.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase II will result in a new type of low-cost Nb_3Sn A-15 multifilamentary superconducting wire with enhanced critical magnetic field (J_c) in intermediate and high magnetic fields. The current and next generation of superconducting magnets for fusion, particle accelerator, and nuclear magnetic resonance (NMR) all require such an advanced superconductor.

TechnoConcepts, Inc.
2363 Teller Road, Suite 118
Newbury Park, CA 91320

A Gallium Arsenide 16-Bit Sigma-Delta Analog-to-Digital Converter with a 100 Megahertz Conversion Rate

High speed (20 - 200 MHz), high resolution (16 bits) analog to digital converters (ADCs) can perform an important role in the electronic instrumentation used in high energy physics. Gallium arsenide (GaAs) would seem to be an optimum technology for this application because of its inherent radiation tolerance. However, some of its limitations have prevented its use in ADCs thus far. During Phase I, the feasibility of using the high speed capabilities of GaAs to implement an oversampling converter with a 100 MHz conversion rate was investigated. Through the use of novel design techniques, a design for such a converter which could operate from the single 5.2V supply was developed. In Phase II, the primary technical objective is to achieve the capability to deliver working prototypes of the 16-bit sigma-delta converter integrated circuit. The activities will include fabricating test circuits for evaluating the design of key ADC building blocks, fabricating and characterizing a complete first order sigma-delta converter, developing a viable test methodology to verify 16-bit performance, and fabricating, characterizing, and delivering working prototypes of the 16-bit converter.

Anticipated Results/Potential Commercial Applications as described by the awardee: The results of this research can be used to develop high speed analog to digital converters in the 100 - 200 MHz speed regime for use in high energy physics research, commercial digital radio, high definition television (HDTV), and high speed instrumentation and telecommunications. The technology developed is applicable to high speed pulse code modulation (PCM) encoding as well.

The Lektrox Company
10301 Bellwood Avenue
New Port Richey, FL 34654

Improved Control of Pulp and Chip Refining Through Direct Measurement of the Number and Severity of Fiber Impacts

The purpose of pulp refining is to produce fibers which have good papermaking qualities. The objectives of Phase I were to construct a sensor incorporating new methods for measuring electrical impulses in the refiner housing, to demonstrate the capability of this sensor to acquire and process the signal in a pilot plant refiner on a single wood species, and to show that the acquired signal correlates with traditional methods for measuring refining results, such as horsepower days per ton, pulp freeness, and the physical properties of hand sheets made from these pulps. These objectives have been met. It is well known in the industry that there are many process variables which influence a given pulp's response to refining action. A major objective of Phase II is to learn how these variables influence the output of the new sensor and to what extent this new measurement, derived from the refining action itself, predicts both drainage and paper properties for a wide range of typical mill conditions. These typical conditions will include other types of pulp, e.g. bleached, hardwood, and recycled. The effects of pH, conductivity, and zeta potential will also be determined. These results will lead to the development of a control strategy which will be demonstrated in a mill site. Other important objectives of Phase II will be to determine the capability of the sensor to measure and control chip refining, and to evaluate and optimize refiner plate design. Also, some fundamental studies of the phenomenon will be imitated at a research institute.

Anticipated Results/Potential Commercial Applications as described by the awardee: The use of this sensor for pulp refining will permit greatly improved control of the process, resulting in energy conservation, quality improvement, and productivity increase. Aggregate energy savings may be as high as 6.5 X 10^{12} BTU/year for pulp refining and 4 X 10^{12} BTU/year for chip refining. Additional savings in papermaking as a result of a more uniform input to the paper-making machines could be more than $500,000 per year per machine. Greater use of recycle pulp will become possible to aid the industry in meeting one of its environmental goals.

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Viscoustech
2836 Ridge Drive
Allison Park, PA 15101-2511

A Torsional Rheometer for Measuring the Properties of Coal and Coal-Water Slurries

Solids and slurries handling processes and equipment are quite inefficient when compared to equipment that handle liquids and gases. This is primarily due to a lack of a clear understanding of the behavior of granular materials and slurries. In Phase I, a torsional rheometer was designed. The use of this rheometer will lead to a better characterization of the properties of granular materials and slurries. In Phase II, this rheometer will be fabricated and calibrated. The rheometer has a cup and plate assembly between which the material is placed. The cup is fixed while the plate is capable of rotating and/or oscillating torsionally about their common axis. The cup and plate are removable. The unique rheometer design also allows the use of either sintered porous disks or impervious disks for the cup and plate. The sintered porous disk design allows the fluidization of granular materials, and the impervious disk design allows the measurement of the properties of slurries. A dynamometer on the shaft of the bottom cup assembly measures the three dynamic components and the dynamic reaction torque experienced by the bottom cup. A rotating dynamometer mounted on the shaft of the top plate also provides the three dynamic force components and the dynamic torque. The spacing between the plates and the motion of the motor is also controlled by the computer. The data from the top and bottom dynamometer are correlated to determine the material moduli, using a computer data acquisition system and software. A rheometer will be manufactured that can measure the properties of granular materials, using a computer data acquisition system and software.

Anticipated Results/Potential Commercial Applications as described by the awardee: The use of this rheometer will result in better designs for solids handling equipment like bins, silos, hoppers, chutes, hydrocyclones, agricultural grain dryers and combustors, and in the transportation of solids and fluidized beds. Since the inefficient performance of these various devices has contributed to inefficient plants and sometimes their failure, better rheological characterization of slurries should lead to tremendous savings. It should also lead to significant savings in other industries involved in surface finishing, and make possible measurement of all the material moduli of blood, needed for design of the artificial heart.

[illegible]

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE II AWARDS

1993

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager
Washington, D.C. 20585

DOE/ER-0600

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PREFACE

The Federal SBIR Program

This program, now completing its eleventh year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Eleven Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over $100 million. The agencies were required to set aside 1.5% of those budgets in Fiscal Year (FY) 1993 to fund SBIR projects. (This amounted to about $50 million in FY 1993 for the Department of Energy.) Each agency solicits proposals from small science- and technology-based US firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to $50,000 in FY 1992. Phase II is the principal research or R&D effort, and the awards were as high as $500,000 in FY 1993 for work to be performed in a period of up to two years. Phase III is the commercial application of the research or R&D effort by the small businesses using non-Federal funding or, alternatively, it may involve follow-on non-SBIR Federal contracts for products or services desired by the Government. The program continues to strengthen the role that small, innovative firms play in meeting the Nation's research and development needs and in commercialization of ideas developed through federally funded R&D.

Phase II Awards for FY 1993

Contained in this booklet are abstracts of the Phase II awards made in FY 1993 under the DOE SBIR program.

DOE received 1534 grant applications in response to its annual solicitation, and on May 22, 1992, 202 were selected for Phase I funding. The Phase II SBIR program competition was limited to the 198 projects that subsequently proceeded to Phase I awards.

Applicants desiring to maintain project funding continuity from Phase I to Phase II were invited to submit their grant applications to DOE not later than December 23, 1992, approximately 6 weeks before the end of their Phase I grants. Sixty Phase II applications were submitted by that date, and 24 were selected for Phase II awards; those projects were then able to continue without funding interruption between Phases I and II. The deadline for the submission of Phase II applications for applicants not seeking to maintain project funding continuity was March 26, 1993. From the 120 applications submitted by this date and from the 36 unfunded applications from the December 23, 1992, submissions, 46 were selected for Phase II awards. The 70 Phase II projects described in this book consist of these 46 projects and the 24 projects that were funded from the December 23 submissions. The listed amount of each award, in many instances, is subject to completion of award negotiations.

The DOE SBIR Program

DOE's FY 1992 annual Solicitation contained 35 technical topics in the areas of basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, energy efficiency and renewable energy, fossil energy, and nuclear energy. There is keen competition because awards are made solely on the basis of scientific and technical merit, regardless of the technical topic.

As a measure of the program's success, ten DOE SBIR projects have received R&D-100 Awards from Research and Development Magazine, which selects the 100 most significant technical products each year. In addition, five DOE awardees were chosen among the 500 fastest-growing American private companies, in the December 1991 issue of Inc. Magazine, based on their growth in sales. Also, from the first five cycles of awards (Phase II projects completed between 1986 and 1990), DOE SBIR winners have already received over $230 million in Phase III funding, which is more than 50% larger than the SBIR support they were given. This number is expected to grow significantly in the next few years.

The DOE SBIR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. In the first year of Phase II awards (1984), a system was devised and implemented that allowed Phase I awardees who felt they were ready to submit their Phase II proposals before their Phase I grants ended, to do so. For each of the ten years in which Phase II awards have been made, such grantees who were chosen for Phase II funding were able to begin their projects without an interruption in funding. Since 1984, about 40 per cent of the Phase II awardees have had continuous funding between Phases I and II.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, DOE has instituted a special training project, supported by non-SBIR funds. For the past four years, successful Phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participation in the 1991 project, the SBIR companies have already received more than $5.5 million for commercialization of their SBIR research, with a projected royalty stream from option agreements of an additional $24 million over the next five years. About 43% of the firms that completed the project have received further funding for their work.

The SBIR program enables DOE to obtain effective, innovative solutions to important problems through the private sector, which has a commercial incentive to pursue the resulting technology and bring it to the marketplace. The growing number of awardees, many of them started in business in response to SBIR solicitations, is becoming a significant resource for the solution of high risk, high technology problems for the Department.

Samuel J. Barish
SBIR Program Manager
US Department of Energy
Washington, DC 20585

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HIGH PERFORMANCE COMPUTING RESEARCH

1

Parallelization Strategies for Smooth-Particle Hydrodynamics--Mission Research Corporation, 735 State Street, P.O. Drawer 719, Santa Barbara, CA 93102-0719; (805) 963-8761
Dr. Thomas P. Hughes, Principal Investigator
Mr. Scot R. Fries, Business Official
DOE Grant No. DE-FG03-92ER81298
Amount: $499,313

Smoothed Particle Hydrodynamics (SPH) is a fully Lagrangian technique for modeling the hydrodynamic behavior of gases, liquids, and solids. Originally developed for astrophysics problems, SPH is becoming a versatile numerical method well-suited to modeling high-velocity impact, laser-target interactions, and implosion/explosion physics. In three dimensions (3-D), SPH has unrivaled simplicity as a Lagrangian technique because it dispenses entirely with a grid. Because of its simplicity in 3-D, SPH is an excellent candidate for exploiting the capabilities of the latest generation of massively parallel computers. These machines offer the memory and speed needed for high-fidelity simulation of the hydrodynamic behavior of complex 3-D objects. Phase I successfully developed the basic parallel algorithms required for SPH on distributed-memory multi-processors. The performance of these algorithms was implemented and measured on a 16-node Intel iPSC/860 computer. Phase II will produce an efficient, parallel, 3-D SPH code on a large-scale parallel machine such as the Intel Paragon currently undergoing acceptance testing at Sandia National Laboratories. This goal will be achieved by overlapping computation and communication, developing an accurate computation-weighted load-balancing scheme, and detailed performance profiling on large numbers of processors. The parallel code developed will be applied to a number of large-scale calculations of current interest at Federal laboratories. When testing is complete, the code will be made available to researchers at these laboratories.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase II will exploit the capabilities of the latest generation of massively parallel computers. It will combine this new technology with an innovative technique for carrying out large-scale 3-D hydrodynamics simulations. Because of its 'pure Lagrangian' nature, SPH is ideally suited to high-fidelity modeling of complex 3-D objects and turbulent fluid motion. The ability to carry out accurate 3-D simulations of impacts involving costly structures such as satellites and missiles under conditions of material failure and fragmentation could result in significantly reduced cost for research in these areas, and allow testing which would otherwise be impractical. The study of laser-target interactions and detonation physics would also benefit.

CHEMICAL SCIENCES RESEARCH

2

Development of a Novel Reverse-Osmosis Membrane with High Rejections for Organic Compounds--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. Scott B. McCray, Principal Investigator
Dr. Rod Ray, Business Official
DOE Grant No. DE-FG03-92ER81422
Amount: $499,911

Chemical process industry separations consume as much as 4.4 quads of energy annually in the U.S. Many of these separations involve removing organic compounds from aqueous process streams. Conventional technologies are energy-intensive or have environmental drawbacks that make their use less than optimal. Futhermore, some processes also destroy the organic compounds, precluding the possibility of recovering or recycling them. Reverse-osmosis (RO) membrane processes offer the potential to significantly improve and simplify treatment of these industrial-process streams, but their use has been limited by their inability to remove many industrially important organics. The goal of this project is to develop a new class of RO membranes that can reject high percentages of organic compounds, while maintaining high water fluxes. These improved organic-rejecting RO membranes could be used alone or in combination with other technologies in hybrid wastewater-treatment systems that would otherwise be impractical, because of the limitations of current RO membranes. Phase I demonstrated the feasibility of this approach by developing membranes with a rejection of 98% for a target organic (phenol) and a water flux of 25 L/m^2-hr. A technical and economic analysis indicates that this performance will result in wastewater-treatment systems with capital and operating costs that are only 60% of the costs for systems based on conventional technologies. Additionally, systems based on the organic-rejecting RO membranes will use only 20% of the energy required by conventional processes. Phase II will (1) continue the development of these organic-rejecting RO membranes, focusing on developing membranes for removal of polar organics, aromatics, and chlorinated hydrocarbons, (2) incorporate these organic-rejecting membranes into solvent-resistant hollow-fiber modules, (3) scale up modules to a size that will allow for meaningful field tests, and (4) field-test the technology extensively. This work will pave the way for immediate commercialization of the technology with the Phase III partner.

Anticipated Results / Potential Commercial Applications as described by the awardee: The commercial applications for this technology are numerous. It will be applicable to a wide range of wastewater-treatment applications, either alone or in hybrid systems with conventional technologies. Initially, the technology would be commercialized for "end of pipe" applications and later would be integrated into existing processes as a "waste reduction" technology.

3

Development of a Process to Synthesize Tubular Fullerenes--Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706; (602) 574-1980
Dr. J. C. Withers, Principal Investigator
Dr. R. O. Loutfy, Business Official
DOE Grant No. DE-FG02-92ER81272

Amount: $500,000

The demonstration that fullerenes (buckyballs) can be produced from a carbon arc has opened a complete new field of science which includes producing nanoscale tubes (buckytubes) that are another facet of carbon's synthetic engineering potential. Buckytubes have been reported by two other groups, but the Phase I program developed processing that achieved substantially higher yields (80%) and tube lengths over three times as long (10μ), as well as a variety of polyhedral structures. The Phase II program plans to optimize the processing to produce further improved buckytubes, optimize the harvesting of the pyrolytic deposit containing the tubes, optimize the fractionating/separating of the tubes from polyhedral shapes and graphite particles, fully characterize the mechanical and electrical properties of the tubes, and produce tubes with preferred mechanical or electrical properties. Activities will be conducted to permit scale-up demonstration and repeatability of optimization processing to synthesize and harvest buckytubes in high quality clean form for application development, and to provide economic estimates for large scale production. Concurrently, fundamental investigations will be conducted to (1) demonstrate doping tubes, (2) establish the mechanism of tube formation, (3) establish reactive properties compared to buckyballs, and (4) determine feasibility of producing very long/continuous tubes. The Arizona Fullerenes Consortium of Universities will provide characterization support and consultation on mechanisms. This program will maintain the U.S. technology lead in fullerene technologies and provide the technology/basis for large scale production of buckytubes.

Anticipated Results / Potential Commercial Applications as described by the awardee: Buckytubes that have molecular dimensions will be produced in controlled diameters and lengths with l/d > 1000 and are expected to have excellent mechanical and electrical properties. The applications will be similar to those for buckyballs, and there may be further applications as reinforcements in all types of matrices, conductors and possibly superconductors.

4

Continuous Production of Fullerenes from Hydrocarbon Precursors–TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033; (303) 940-2301
Mr. John D. Wright, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-92ER81322
Amount: $500,000

Fullerenes, a recently discovered family of closed shell carbon compounds, have a number of exceptional electronic, optical, and chemical properties. However, they must be available at a reasonable price if they are to find commercial application. Unfortunately, the carbon arc process currently used to produce fullerenes is inherently slow and expensive. The goal of this project is to develop a continuous process using hydrocarbon precursors to produce large quantities of low cost fullerenes. In Phase I, research quality production apparatus was built and demonstrated. Yields and rates of production were achieved which allowed the production of mixed fullerenes for a small fraction of the current price. The chief advantages of the process are continuous operation, high production rates, and low power consumption. Phase II will determine how temperature, pressure, hydrocarbon concentration, and fuel structure affect the yield and rate of production. These experiments will be carried out in a reactor with well-defined temperature and flow profiles. Using this information, production reactors with two different geometries will be designed, built, and tested. With information from the prototype production reactors, a large scale (multi-kg/day) production reactor will be built in Phase III.

Anticipated Results / Potential Commercial Applications as described by the awardee: Although fullerenes have unique chemical and electronic properties, their price is currently so high ($100 to $200/g) as to preclude commercial applications. The production process of this project has the potential to reduce the cost of fullerenes by a factor of ten to twenty when operated at the laboratory scale. A scaled-up process might process fullerenes for less than 5¢/g ($15/lb.).

5

Preparation of Low-Density Microcellular Materials from Fullerenes–TDA Research, Inc., 12345 West 52th Avenue, Wheat Ridge, CO 80033; (303) 940-2301
Dr. William L. Bell, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-92ER81320
Amount: $500,000

Low-density microcellular materials (LDMMs) are carbon- or silica-based porous solids with a range of potential applications. In Phase I, novel monolithic fullerene-based LDMMs of two kinds were prepared: (1) Water soluble fullerene derivatives were prepared and polymerized to form gels, which were processed by supercritical extraction to yield organic aerogel LDMMs. These fullerene-based organic aerogels have high specific surface area (290-540 m^2/g), high porosity (46%), and small average pore size (6-10 nm). (2) A new fullerene/silicon precursor, soluble in organic solvents, was prepared and polymerized to produce silica gels in which a fullerene is incorporated molecularly into the silica network. These gels have been prepared in the form of thin films on glass or on silicon, free-standing films, powders, and xerogels. The goal of Phase II is to develop further the novel fullerene-based organic and inorganic LDMMs and systematically explore the relationships between the processing conditions and the properties of the resulting materials. Phase II will first systematically study the fullerene precursor materials and the synthetic chemistry involved in the formation of both the fullerene-organic aerogels and the fullerene-silica gels prepared in Phase I. There will also be development of fullerene-metal oxide (alumina, titania, silica-alumina, and silica-titania) LDMMs with various forms such as powder, thin films, xerogels, and aerogels. The fullerene derivatives and their resulting organic and inorganic LDMMs will be thoroughly characterized by determining their structure, elemental composition, thermal stability, morphology, apparent density, specific surface area, pore size distribution, and mechanical strength. In addition, the pyrolysis chemistry of these fullerene LDMMs will be studied by pyrolyzing them in an inert atmosphere at various temperatures and characterizing the resulting products in aspects such as microstructure and conductivity. The catalytic properties of the fullerene LDMMs will be investigated by screening their catalytic activity in typical applications. Finally, market and engineering analyses will be performed to identify the areas in which these novel materials show the best potential application.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase II will result in improved porous solids based on fullerene carbon. These materials have potential application as catalysts and catalyst supports, and as electrode materials and electrochemical sensors. Based on current work with LDMMs, the new materials may also find application as sorbents and as components of structural composites.

MATERIALS SCIENCES

6

Digital Processing Electronics for X-Ray Detector Arrays--X-Ray Instrumentation Associates, 1300 Mills Street, Menlo Park, CA 94025-3210; (415) 903-9980
Dr. William K. Warburton, Principal Investigator
Dr. William K. Warburton, Business Official
DOE Grant No. DE-FG03-92ER81311
Amount: $500,000

Many areas of synchrotron radiation investigation are severely detector limited, particularly in cases where single photon, energy dispersive counting is required. Because the maximum count rate for a single detector at a given energy resolution is limited, arrays of detectors are being constructed to increase total count rates. This approach is presently restricted by the cost, physical size, and complexity of the required analog processing electronics. In Phase I, detailed studies were performed, investigating the possibility of developing digital processing electronics based on concepts of digital signal processing. By both hardware and software modeling studies, it was shown that it is possible to match the resolution of current analog systems while increasing maximum throughput by a factor of 2, decreasing costs by factors of 4 to 8, and reducing physical size by an order of magnitude. If these gains can be demonstrated in practice, then arrays with 100 or more channels will become practical. Phase II will address the issues involved in physically realizing a digitally based signal processing system. The work is particularly directed toward resolving issues of signal preconditioning, constructing a hardware filter and control system, and demonstrating a route to cost effective commercialization. A successful project will result in a working demonstration unit.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project should result in the development of digital processing electronics for energy dispersive x-ray detectors which offer improved high rate performance at lower cost than existing analog processing electronics. These electronics are particularly well suited for instrumenting arrays of energy dispersive detectors with large numbers of channels for research applications at third generation synchrotron sources.

7

A Cold/Thermal Beam Bender Using Capillary Optics to Increase the Number of End-Guide Instrument Positions--X-Ray Optical Systems, Inc., 1400 Washington Avenue, Physics, Albany, NY 12222; (518) 442-5250
Dr. Qi-fan Xiao, Principal Investigator
Mr. David M. Gibson, Business Official
DOE Grant No. DE-FG02-92ER81411
Amount: $500,000

The use of promising non-destructive cold and thermal neutron material analysis techniques has been hindered by the limited availability of high-flux sources of low-energy neutrons. This project will develop neutron benders which would transmit a wide wavelength range of cold and thermal neutrons through a small radius of curvature, enabling the creation of several end positions on a single guide. This neutron optics utilizes glass capillaries with small diameter channels through which the neutrons make multiple reflections at less than the critical angle of reflection. Phase I demonstrated high transmission efficiency through individual polycapillaries which were over 50 cm long and deflected the beam by more than 10°. Computer simulations and experimental results were in very good agreement for borosilicate glass. The design and construction of a neutron bender for Prompt Gamma Activation Analysis (PGAA) and Small Angle Neutron Scattering (SANS) was determined to be feasible. Phase II will develop and test full size prototypes customized for prompt gamma activation analysis and small-angle neutron scattering. The optics design will be tailored to meet the application requirements: providing filtration of gamma rays and epithermal neutrons, collimating the beam, and/or focusing the beam for good spatial resolution. Phase II will involve collaboration with experienced personnel from multiple reactor sites.

Anticipated Results / Potential Commercial Applications as described by the awardee: A successful neutron beam bender will increase the number of experiments and measurements that can be performed using cold and thermal neutrons without the expense of adding neutron guides or reactors. This will enable material analysis techniques such as PGAA and SANS to be much more widely utilized. Technologies that would benefit are those involving high performance materials such as semiconductor, polymer science, metallic alloys, coatings, and superconductors. Sales of neutron beam benders would be to cold and thermal neutron sources internationally, both at steady state reactors and at pulsed spallation neutron sources.

HUMAN GENOME

8

Spatially Defined Oligonucleotide Arrays--Affymetrix, Inc., 3380 Central Expressway, Santa Clara, CA 95051; (408) 481-3410
Dr. Stephen P.A. Fodor, Principal Investigator
Dr. Stephen P.A. Fodor, Business Official
DOE Grant No. DE-FG03-92ER81275
Amount: $500,000

In Phase I, spatially defined arrays of oligonucleotide probes were constructed and used to study the feasibility of sequencing DNA by hybridization. To accomplish this result, newly developed techniques in light directed polymer synthesis were applied to oligonucleotide chemistry. Kinetic and solvent related parameters of target hybridization to the oligonucleotide arrays were explored and the positions of hybridization were read by epifluorescence microscopy. Phase II will improve the basic technology by (1) developing advanced instrumentation including high speed detection systems, (2) upgrading the image analysis software to handle large images automatically, and (3) developing algorithms for the design of application-specific dedicated arrays of probes.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful completion of this project will lead to a method for rapid, inexpensive fabrication of oligonucleotide arrays. The oligonucleotide arrays can be applied to the Human Genome effort for high-throughput sequencing by hybridization, and other efforts in genetic fingerprinting and genetic mapping. Scale up of this technology can be used to provide oligonucleotide templates to national, university, and commercial laboratories investigating applications of hybridization technology. The oligonucleotide arrays will find commercial application in genetic diagnostics.

9

Rapid, High-Throughput DNA Sequencing Using Confocal Fluorescence Imaging of Capillary Arrays--Molecular Dynamics, 880 East Arques Avenue, Sunnyvale, CA 94086; (408) 737-3000
Dr. David L. Barker, Principal Investigator
Mr. Jay Flatley, Business Official
DOE Grant No. DE-FG03-92ER81299
Amount: $500,000

The goals of the Human Genome Project require techniques for DNA sequencing that increase throughput over current methods by an order of magnitude or more. Current automated fluorescence sequencing instruments require several hours for a single gel run and accommodate a maximum of 36 reaction sets. Capillary gels can be run at higher voltages to yield separation of 300-500 bases in 1-2 hours, but current fluorescence detection methods are limited to analyzing one capillary at a time. Confocal fluorescence imaging has the capacity to produce high-sensitivity detection with the geometrical advantage that excitation light is delivered through the same lens that collects fluorescence emission. R.A. Mathies and his colleagues have shown that a single scanning confocal fluorescence detector can detect DNA fragments in a parallel array of capillaries. Phase I was directed toward testing the feasibility of this technology for high-throughput DNA sequencing, including automated methods to load and analyze up to 96 reaction sets simultaneously in 1-2 hours. Phase II will identify and test various dye chemistries, lasers, base coding methods, and software analyses with the goal of identifying solutions that would be successful in a commercial instrument. It will also test low-viscosity gel matrices and design and build a capillary array filling and flushing system. A working prototype capillary array sequencer will be built for testing in a high-throughput laboratory.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will demonstrate the practicality of developing a cost-effective commercial instrument for high-throughput DNA sequencing. A capillary array DNA sequencer would advance the goals of the Human Genome Project and could become the method of choice for academic, government, and biotechnology laboratories doing DNA sequencing.

10

Chemiluminescent Multiprimed DNA Sequencing--Tropix, Inc., 47 Wiggins Avenue, Bedford, MA 01730; (617) 271-0045
Dr. Chris S. Martin, Principal Investigator
Dr. Irena Bronstein, Business Official
DOE Grant No. DE-FG05-92ER81389
Amount: $500,000

The objective of this project is to develop research kits for performing DNA sequencing and PCR analysis utilizing a multiplex labeling approach and chemiluminescent detection. Phase I demonstrated the feasibility of increasing the amount of DNA sequence information which can be determined from one membrane by separating multiple sets of DNA sequencing reactions in each gel lane, transferring the DNA to nylon membrane, and detecting each set of sequencing reactions individually with 1,2-dioxetane substrates for alkaline phosphatase. This was accomplished by utilizing multiple DNA sequencing primers, each with its own unique label, and detecting each set of DNA sequencing reactions sequentially with alkaline phosphatase conjugates specific for each label. Various labels and enzyme conjugates were evaluated for performance. Phase II will further optimize the procedure for the sequential detection of each set of labeled fragments and will incorporate the newly developed protocols and the individual reagents into a research kit which will become a useful tool for molecular biologists, DNA sequencing, and PCR product analysis. A DNA sequencing reaction kit with multiple hapten labeled primers and a complementary chemiluminescent detection kit containing hapten specific enzyme conjugates will be produced. The chemiluminescent detection kit will also be useful for the sequential identification of overlapping PCR products. The creation of a specific membrane optimized for chemiluminescence will be investigated. In addition, an apparatus for automating the blot development steps will be utilized, increasing throughput and permitting system scale up. Techniques for interfacing the multiplex labeling DNA sequencing procedures with PCR amplification and single stranded DNA template purification will also be developed. Protocols for these techniques will be incorporated into the research kits and will greatly expand their utility.

Anticipated Results / Potential Commercial Applications as described by the awardee: DNA sequencing is an integral part of many research programs, and has until recently been performed solely with the use of radioactive isotopes. Environmental and safety concerns demand the development of more efficient and non-radioactive methods for the DNA sequence determination. Research kits will be developed for performing DNA sequencing and PCR analysis with multiplex labeling and chemiluminescent detection using

1,2-dioxetane substrates for alkaline phosphatase. Membranes which exhibit optimum signal to noise characteristics when performing multiple chemiluminescent detections will be produced.

MEDICAL APPLICATIONS

11

New Gadolinium-Boron Compounds for Neutron Capture Therapy--Boron Biologicals, Inc., 533 Pylon Drive, Raleigh, NC 27606; (919) 832-2044
Dr. Bernard F. Spielvogel, Principal Investigator
Mr. Todd Bishop, Business Official
DOE Grant No. DE-FG05-92ER81412
Amount: $500,000

Neutron capture therapy (NCT) is a very promising therapy for certain tumors, such as gliomas and melanomas. There are several nuclei which have high cross sections for thermal neutrons, of which ^{10}B and ^{157}Gd have been shown to be very promising. Boron-10 has a high cross section for thermal neutrons and has a very versatile chemistry. Gadolinium-157 has the highest cross section for thermal neutrons and, being paramagnetic, is good for magnetic resonance imaging. A combination of these two nuclei in a single entity should provide a single, more convenient way of tumor diagnosis and treatment. In Phase I, two cyclen ligands, 1,4,7-tris(carboxymethyl)-10-(phenylpropyl)-1,4,7,10-tetraazacyclododecane and the corresponding nido-carboranylpropyl derivative were synthesized. The phenylpropyl cyclen was reacted with gadolinium oxide to give the gadolinium complex. Additionally, this complex has also been prepared with enriched ^{157}Gd for imaging and NCT studies. Attempts to prepare the gadolinium complex of a nido-carboranylpropylcyclen ligand were unsuccessful due to the instability of a nido-carborane cage under the conditions required for complex formation. A more stable carborane cage, such as m- or p- or monocarbaborane should alleviate this problem. Phase II will focus on (1) further modifications of the cyclen ligands to increase stability, water/or lipid solubility, and boron content of complexes, and (2) designing methods to deliver and concentrate boron-gadolinium complexes in the tumor. The newly synthesized compounds will be evaluated for magnetic resonance imaging, in vitro and in vivo efficacy for neutron capture therapy of cancer, and short term toxicity.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of Phase II should provide one or more new boron-containing gadolinium complexes which can be successfully used for magnetic resonance imaging of tumor tissue, followed by tumor destruction by neutron capture.

12

Imaging Systems for Biomedical Applications--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523; (914) 592-1190
Dr. Masoud Radparvar, Principal Investigator
Dr. Hollis L. Caswell, Business Official
DOE Grant No. DE-FG02-92ER81407
Amount: $499,975

Many of the activities of the human body manifest themselves by the presence of a very weak magnetic field outside the body, a field that is so weak that an ultra-sensitive magnetic sensor is needed for specific biomagnetic measurements. Superconducting quantum interference devices (SQUIDs) are extremely sensitive detectors of magnetic flux and have been used extensively to detect the human magnetocardiogram and magnetoencephalogram and other biomagnetic signals. In order to utilize a SQUID as a magnetometer, its transfer characteristics should be linearized. This linearization requires extensive peripheral electronics, thus limiting the number of SQUID magnetometer channels in a practical system. The digital SQUID integrates the processing circuitry on the same cryogenic chip as the SQUID magnetometer and eliminates the sophisticated peripheral electronics. Such a system will be compact and cost effective, and require minimal support electronics. This project will lead to the development of thin-film digital magnetometer/gradiometer chips. Each chip, in addition to having on-chip processing circuitry coupled to a SQUID, will also have an integrated superconducting transformer to facilitate its interface to an external pick-up coil. As a result of this effort, it will be possible to design and fabricate single chips that will contain arrays of digital SQUIDs for integration in a multi-channel SQUID system, thereby reducing the cost and complexity of such systems. The major cost associated with the present SQUID-based biomagnetometer systems is the shielded room environment, which can be as much as $1 million. The digital SQUID significantly relaxes the requirements on the low frequency magnetic field shielding and reduces the shielding cost considerably. Significant cost savings are also realized by eliminating much of the peripheral electronics, thus allowing multi-channel systems to be built very cost effectively. In Phase I, a one-bit digital SQUID magnetometer was designed, simulated, fabricated, and evaluated. The validity of the concept was demonstrated. Phase II will optimize the design of the digital SQUIDs, with feedback circuitry developed during Phase I, using niobium technology. Development activities will lead to the design, fabrication, and evaluation of an optimized multibit SQUID chip.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will lead to the development of an all-thin film SQUID chip for use as an ultra-sensitive magnetometer. The chip is a self-contained magnetometer with on-chip processing circuits and will require minimal support electronics. Consequently, arrays of such chips can be realized very cost effectively for integration in multichannel SQUID magnetometer systems for use in non-invasive biomedical instruments such as multi-channel magnetocardiograms and magnetoencephalograms.

PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

13

Refractory Metal Coatings on Carbon/Carbon Composites for First Wall Applications--Applied Sciences, Inc., 141 West Xenia Avenue, P.O. Box 579, Cedarville, OH 45314; (513) 766-2020
Mr. Jyh-Ming Ting, Principal Investigator
Mr. Max L. Lake, Business Official
DOE Grant No. DE-FG02-92ER81416
Amount: $500,000

Joints between high heat flux materials and cooling lines, required for fusion plasma facing components, must have mechanical strength adequate to withstand stresses or strains generated thermally and/or mechanically, and must also have high thermal conductance to provide for efficient heat transport. A novel approach to joining, involving a combination of low temperature processes, has demonstrated excellent control of the interface reaction. In Phase I, the interface properties were controlled by using ion beam enhanced deposition (IBED) on the surface of carbon/carbon composites or of beryllium. This allowed the formation of a graded interface layer on the surface, to alleviate coefficient of thermal expansion mismatch, and an additional high strength surface layer to be deposited for subsequent bonding to copper. Using IBED, pure copper and silver were mixed and deposited into the surface of carbon/carbon composites and beryllium, respectively. Implantation of copper into the carbon/carbon composite was shown to facilitate a mechanically robust graded interface of copper and carbon. The thermal conductance of the joint was measured, and appears to be a promising non-destructive test for the reliability of the joint between plasma facing materials and cooling structures. Phase II will fully explore the joining methodology by refining the process, evaluating the bonding characteristics, and developing a prototype first wall tile to cooling structure assembly. Both beryllium and high thermal conductivity carbon/carbon composites will be studied as candidate plasma facing materials using this approach.

Anticipated Results/Potential Commercial Applications as described by the awardee: Development of technology for high integrity thermal and mechanical joints will enable the exploitation of advanced high temperature materials, including beryllium and carbon/carbon composites for high performance applications such as for fusion first wall components, heat sinks in electronics, and space-based radiators.

14

A Thermal Composite Plasma Facing Material--Energy Science Laboratories, Inc., 6888 Nancy Ridge Drive, San Diego, CA 92121-2232; (619) 552-2034
Dr. Timothy R. Knowles, Principal Investigator
Dr. Timothy R. Knowles, Business Official
DOE Grant No. DE-FG03-92ER81283
Amount: $500,000

This project will develop a high thermal conductivity carbon composite armor tile that has excellent chemical and physical sputter resistance. A novel fiber carpet preform enables deposition of highly anisotropic carbon in which the high conductivity direction is oriented entirely through the thickness of the tile. Although the fiber preform is unidirectional, the grain structure of the infiltrated carbon is expected to have good thermal shock resistance and controllable thermal expansion characteristics. Phase I demonstrated that the high surface area of the separate fiber carpet preform allows rapid densification by vapor infiltration. Based on Phase I, it is anticipated that high-density centimeter-thick armor tiles can be deposited in tens of hours. The thermal conductivity through the thickness of the full density heat-treated tiles is expected to lie in the range 1000 - 2000 W/m-K. Using shorter infiltration time, a high-aspect ratio vertical fiber carpet structure roughness and high physical sputter resistance should reduce both the rate of surface erosion and the rate of accumulation of redeposited carbon, resulting in less tritium retention. Phase II will focus on materials processing, including fabrication of the fiber preform, infiltration with high density anisotropic carbon, and high temperature compressive annealing. Preliminary temperature cycling, thermal conductance, and sputter rate measurements will be performed. Samples will be prepared for high flux testing, sputter erosion testing, and plasma environment testing at DOE-sponsored facilities. Depending on the test results, a tokamak application will be selected, and an illustrative full-scale armor tile will be fabricated.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project should lead to improved plasma confinement materials having higher heat conductance and reduced erosion, as required for tokamak fusion programs such as the International Thermonuclear Experimental Reactor (ITER). Other potential applications are: high shock-resistance baffles and fixturing for inertial confinement fusion, low-debris baffles for pulsed X-ray generators, and heat spreading substrates for high power electronics.

15

A Niobium-Tin Multifilamentary Composite Superconductor with Artificial Copper (Bronze) Inclusions--Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545; (508) 842-0174
Dr. Dingan Yu, Principal Investigator
Ms. Elaine Drew, Business Official
DOE Grant No. DE-FG02-92ER81387
Amount: $499,848

The purpose of this project is to develop a new type of low-cost niobium-tin (Nb_3Sn) multifilamentary superconducting wire using copper (Cu) (bronze) as the artificial flux pinning centers to enhance critical current densities of the conductor in intermediate and high magnetic fields. Very high non-Cu critical current densities of greater than 1900 and 1000 A/mm^2 at fields of 9 and 12.5 tesla, respectively, were achieved in the internal-tin type of conductor samples prepared in Phase I using a jelly-roll technique. There is evidence that the Cu inclusions artificially introduced into the A-15 matrix increase the critical current densities in A-15 layers about 15%, compared with the sample without Cu inclusions in filaments. Phase II will continue work on optimization of the amount of Cu in filaments, Cu-to-Cu spacing, filament size, processing and heat-treatment parameters, in order to further increase the current-carrying capability of the conductor at magnetic fields greater than 10 tesla. The most promising conductor will be scaled up in size and quantity, aiming for fusion applications such as the International Thermonuclear Experimental Reactor (ITER), by using a double-restacking technical approach.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase II will result in a new type of low-cost Nb_3Sn A-15 multifilamentary superconducting wire with enhanced critical magnetic field (J_c) in intermediate and high magnetic fields. The current and next generation of superconducting magnets for fusion, particle accelerator, and nuclear magnetic resonance (NMR) all require such an advanced superconductor.

16

A Porous Metal Heat Exchanger Cooled Gyrotron Microwave Cavity--Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601; (717) 569-6551
Mr. John H. Rosenfeld, Principal Investigator
Mr. Richard W. Longsderff, Business Official
DOE Grant No. DE-FG05-92ER81427
Amount: $499,794

Power output of gyrotrons used in the fusion program is presently limited by the cooling of the microwave cavity. Existing designs can extract a heat flux of 1-3 kW/cm^2. The Russians have reported 4-5 kW/cm^2 using porous metal heat transfer. In a porous metal heat exchanger, single-phase (gas or liquid) coolant flows through a thin porous layer beneath the heat exchanger faceplate. High cooling rates are due to the large surface area of the porous layer. Phase I considered use of porous metal heat transfer for cooling of a gyrotron cavity. A copper/water porous metal heat exchanger test article survived multiple heating cycles at heat fluxes of 4 to over 6 kW/cm^2. Failure occurred at an absorbed heat flux of 7.45 kW/cm^2. A preliminary design of a gyrotron cavity was completed, based on porous metal heat transfer. The selected design shows promise for achieving heat fluxes of 5 to 10 kW/cm^2, which will eliminate microwave cavity cooling as the limiting factor in the gyrotron power layer. In Phase II, a full-scale porous metal cooled cavity will be designed, built, and tested. Tests will be conducted to demonstrate that the approach can survive high heat fluxes and fatigue stresses typical of the cavity environment.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will utilize porous metal heat transfer to achieve cooling rates of 5 to 10 kW/cm^2 and eliminate microwave cavity cooling as the limiting factor in gyrotron power output. Another potential application for porous metal heat exchangers would be to cool the exhaust valve seats in internal combustion engines; this would allow somewhat higher temperatures in the cylinders and improve overall efficiency. Porous heat exchangers are not limited to metals. Porous medium heat exchangers of silicon carbide would open new applications for extremely high-powered semiconductor devices such as laser diodes, and could also be used for cooling of high-powered optics.

PLASMA DIAGNOSTICS

17

A High Energy Far-Infrared Source for Collective Thomson Scattering Diagnostics--John R. Bayless Company, 20325 Seaboard Road, Malibu, CA 90265; (818) 707-1131
Dr. Andras Kuthi, Principal Investigator
Dr. John R. Bayless, Business Official
DOE Grant No. DE-FG03-92ER81290
Amount: $500,000

A critical need exists for a diagnostic instrument to measure the energy distribution and density of confined energetic ion components in D-T burning fusion tokamaks (e.g. confined alpha-particles with 3.5 MeV birth energy). Collective Thomson Scattering (CTS) is recognized as the most attractive approach for obtaining this information. Based on the analyses performed in Phase I, a CO_2 laser-pumped far-infrared (FIR) laser operating at a wavelength of 152 µm offers the optimum source for this CTS application. This compact, low-cost laser source would be operated in a repetitively pulsed mode (30 Hz) with moderate pulse length (2µs) and energy (~1 J/pulse). High signal-to-noise will be achieved by integrating over ~10 pulses. The advantages of the FIR source are: (1) avoidance of density and plasma absorption/emission limits, and lower cost relative to gyrotrons; (2) much lower cost, size, and complexity relative to free-electron lasers and (3) a larger scattering angle and a lower cost receiver system relative to a 10 µm laser source. A laboratory prototype 152 µm laser system will be developed and demonstrated in Phase II. This laser system will be designed to deliver a minimum of 0.5 J (possibly up to 1 J) in 2 μs pulses at a repetition rate of 30 Hz in 10-pulse bursts. These parameters are adequate to measure the characteristics of the bulk and energetic ions in the Alcator C-MOD tokamak. A highly qualified team, combined with the incorporation of key elements of existing hardware, will help to ensure the success of Phase II. Moderate extensions of the technology that will be demonstrated in Phase II will be very attractive for making CTS measurements in the International Thermonuclear Experimental Reactor (ITER). Thus, the planned effort will provide a new and innovative source that will enable high quality CTS measurements in present experiments and future D-T burning fusion experiments.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will provide an advanced source technology for use in CTS diagnostic systems which will have important applications in Government-sponsored fusion research projects. The proposed FIR laser technology could serve as valuable U.S. contribution to the ITER effort. The high-performance CO_2 pump laser to be developed as part of the FIR laser system will, itself, be useful for CTS at 10 μm. It will also be very attractive for use in long-range DIAL (differential absorption LIDAR (light detection and ranging)) systems for remote chemical sensing and environmental monitoring. These systems are expected to have many important commercial and Government applications.

18

A Fast Processor of Tokamak Ion Temperatures--
ORINCON Corporation, 9363 Towne Centre Drive, San Diego, CA 92121; (619) 455-5530
Dr. Gary L. Jahns, Principal Investigator
Mr. Richard L. Taylor, Business Official
DOE Grant No. DE-FG03-92ER81301
Amount: $499,898

Charge Exchange Recombination (CER) spectra provide an important measurement of ion temperatures in tokamak experiments, but availability of results has been severely impacted by the analytical computation time. Phase I has demonstrated that it is feasible to estimate tokamak ion temperatures and Doppler shifts with a neural network. This demonstration was performed with a large database of actual CER spectra supplied by the DIII-D project at General Atomics. The parameter estimation process is a straightforward application of neural net learning techniques, using the rigorous analytical best-fit results as the "truth," or training target. A three-layer perceptron was the network configuration used in this study; best results were achieved with hidden layers of 25 nodes each. The error between the output parameters determined by the net and the target truth values was found to be of comparable size to the uncertainty of the truth values. Some of the uncertainty values are in fact quite large, and a further reduction of network output errors may be possible by accounting for the uncertainty when training. The objective of Phase II is to produce an operational system that can accept the stream of CER spectral data, process the data with the neural network of Phase I, and output 8000 ion temperature and Doppler shift estimates within two minutes after the data are available. The planned approach is to configure a dedicated microprocessor system, similar to those employed in other signal processing applications, to meet the present requirements. The planned system is formed from modular hardware in a VME chassis and a mix of pre-existing neural net and new, application-specific software. Detailed analysis is given for the time required for each step in the data transfer and processing chain, using the known performance rates of specified hardware. The system design is cost-effective and meets the processing time requirement with a safety margin of ten. The task breakdown, costing, and schedule indicate that a program in which a programmable real time information image signal processing multichannel (PRISM)-based fast processor will be operational in the second year of the project is achievable.

Anticipated Results / Potential Commercial Applications as described by the awardee: The principal result will be the solution of the CER processing bottleneck problem by virtue of the operational system providing 8000 temperature and shift estimates per discharge. The operational system will represent transfer of defense-agency supported technology. It is expected that similar processors will be applied to CER and other diagnostics at fusion research centers worldwide. The planned system is a major step toward real-time processing of kinetic parameters, necessary for feedback control in the International Thermonuclear Experimental Reactor.

19

A Thomson-Scattering Plasma Diagnostic for Materials Testing and Divertor Concept Testing--Princeton Scientific Instruments, Inc., 7 Deer Park Drive, Monmouth Junction, NJ 08852; (908) 274-0774
Dr. Dirck L. Dimock, Principal Investigator
Mr. John Lowrance, Business Official
DOE Grant No. DE-FG05-92ER81401
Amount: $500,000

The next generation of magnetic confinement fusion research machines, such as the International Thermonuclear Experimental Reactor (ITER), will impose extraordinary demands on the first wall materials in the vacuum vessel and especially the divertors. Phase I has resulted in the conceptual design of a Thomson scattering based plasma diagnostic suitable for measuring the plasma characteristics near boundary surfaces. Such diagnostic measurements are necessary in interpreting the results from testing candidate first wall/divertor materials and divertor operating scenarios for the next generation of magnetic confinement fusion machines. This design is also a candidate for possible feedback control of divertor plasma conditions. The compact design resulting from Phase I should have much broader applications as well. It is suitable as a general Thomson scattering diagnostic for many small plasma devices, and for measurements in otherwise inaccessible regions of larger plasma devices, such as scrape-off plasmas and edge plasma measurements. In Phase II a prototype of the Thomson scattering diagnostic will be designed and built, and made available for use on plasma generator test facilities for materials research and fusion research.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase II will result in the design, construction, and test of a new Thomson scattering plasma diagnostic instrument. The primary commercial application for the planned Thomson scattering instrumentation will be in plasma research, and there is an international market for such systems in fusion and other plasma research such as toxic waste disposal. This system may also be of particular interest as a general Thomson scattering diagnostic for university-scale plasma devices.

20

A High Average Power, High Peak Power Submillimeter Laser--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Stephen Fulghum, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-92ER81383
Amount: $499,989

A high average power (≥1 W), short pulse (100 nsec), narrow frequency, far infrared (FIR) laser is planned, to be pumped by an existing high average power carbon dioxide (CO_2) laser. The system is intended as the master oscillator for a submillimeter-wave, alpha Thomson scattering diagnostic to be installed on the International Thermonuclear Experimental Reactor (ITER). The final diagnostic source will consist of the CO_2 laser pump, a FIR master oscillator, and a free electron laser amplifier. The FIR master oscillator will use either ammonia (NH_3) or monofluoromethane (CH_3F) as the active medium, and will provide 10 kW peak power in the 150 µm wavelength region with a repetition rate of 1000 pps. Gas heating effects require the use of a flow loop and heat exchanger for sustained high repetition rate operation. In Phase I a preliminary engineering design for the FIR laser was completed, including (1) a parametric investigation of the proper CO_2 laser pump intensity for efficient FIR generation, (2) a novel zig-zag ring laser cavity design which separates the windows through which the CO_2 pump laser and FIR circulating beam must pass, and (3) a closed-cycle flow loop with a heat exchanger and a magnetically-coupled transverse blower for the FIR laser medium. Phase II will begin with the development of a prototype, static-fill, FIR laser to test the ability of the zig-zag ring cavity to produce the required FIR output in single-pulse and burst modes. The flow loop will be engineered, fabricated, and integrated with the laser cavity. The entire FIR laser system will then be tested at a sustained 1000 pps repetition rate.

Anticipated Results / Potential Commercial Applications as described by the awardee: Ultrasensitive spectroscopic trace gas detection systems are being developed which require narrowband tunable pulsed lasers as the light source. This FIR laser system will extend the range of characteristic spectroscopic lines which can be accessed well beyond the limited range of the current CO_2 laser sources. This will significantly increase the ability of these systems to select a specific trace species for measurement in the presence of other species. It is anticipated that the tunable, pulsed FIR laser developed in this project, combined with a laser interferometric calorimeter, will find applications in the detection of atmospheric trace gases at the parts per trillion level.

FUSION ENERGY SYSTEMS

21

Development of Silicon Carbide Ceramic Composites for Fusion Reactor Applications--
Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706; (602) 574-1980
Dr. R. O. Loutfy, Principal Investigator
Dr. J. C. Withers, Business Official
DOE Grant No. DE-FG02-92ER81271
Amount: $500,000

Ceramic/ceramic composites such as SiC fiber/SiC matrix are both enabling and enhancing technology for a variety of advanced systems including fusion applications. Before now, SiC fibers did not possess the chemical, microstructural, and radiation stability at high temperatures for many advanced composite applications. Phase I demonstrated that graphite fiber and cloth/fabric could be converted to a high purity β SiC which had high strength (2.0 - 2.96 gigapascal (GPa)), and a fine microstructure (10-40 nm grain) that maintained these properties after soaking 2000 hours at 1200°C in He and when tested at 1200°C. Composites were fabricated using a variety of SiC matrix processes, which produced high toughness composites of 1.5 - 3.3 times the base Nicalon-CVI SiC composite. CVI and a carbon matrix converted to SiC results in a β SiC reinforcement/β SiC matrix composite which offers significant potential for fusion reactor applications, since it has been established that β SiC has excellent resistance to radiation. Phase II will optimize producing a reliable high strength β SiC reinforcement that was demonstrated in Phase I, and will optimize matrix forming processes to produce β SiC/β SiC composites. These composites will be fully evaluated and optimized for fusion reactor applications. The β SiC reinforcement in select weaves will be supplied to a variety of outside sources to produce chemical vapor infiltration (CVI) and other matrix forming processes, and these composites will also be fully evaluated. Composites will be made available for radiation testing and property evaluation by outside sources. Graphite prewoven architectures, after conversion to a high purity β SiC reinforcement with a strength greater than or equal to 3 GPa that is maintained at 1200°C, does not show degradation of mechanical properties, microstructure, or composition after very long 1200°C exposure in a reactor environment. These excellent properties should remove the materials limitations for fusion reactor applications and significantly advance the state-of-the-art of ceramic/ceramic composites. Phase II will demonstrate such β SiC/β SiC composites.

Anticipated Results / Potential Commercial Applications as described by the awardee: β SiC reinforcements in fiber and fabric architectures will be produced, with strength in the 2-3 GPa range. A neutron radiation resistant interface/debond coating will be developed that provides 1.25 - 2 times the toughness of the current state-of-the-art, to result in a β SiC reinforced/β SiC matrix that has higher temperature strength and thermal stability than any existing ceramic/ceramic composite. This material should have applications for fusion reactors, and also for all gas turbine rotating and combustion components, heat exchangers, internal combustion engines, supersonic vehicles, re-entry vehicles, burner tubes, and chemical process equipment.

22

Radioisotope Production and Actinide Waste Transmutation in Small Fusion Reactors--TSI Research, Inc., 225 Stevens Avenue, Suite 110, Solana Beach, CA 92075; (619) 793-3567
Dr. Edward T. Cheng, Principal Investigator
Dr. Edward T. Cheng, Business Official
DOE Grant No. DE-FG03-92ER81310
Amount: $500,000

Nuclear waste transmutation can be categorized into three scenarios: (1) fission products only, (2) minor actinides (Np, Am, and Cm isotopes) only, and (3) all transuranium isotopes. In Phase I nuclear performance characteristics for the fusion blankets constructed with ferritic steel dedicated for the above transmutation scenarios were identified. For each scenario, the desirable fusion power output of the fusion transmutation reactors (FTRs) was estimated. The total thermal power output of each scenario matches the 3000 MW(th) rating of a typical fission power plant (FPP), and the electric power produced is: Scenario 1 - about 3000 MW; Scenario 2 - about 300 MW; and Scenario 3 - about 30 MW. These are determined based on the blanket energy multiplication. The fusion power and plasma amplification (Q) are likely to be important factors that will influence the economic aspect of the FTRs. Scenarios 2 and 3 FTRs deserve further investigation because they require relatively lower fusion power and plasma Q. Scenario 3 (All trans-uranium elements (TRU) and fission products (FP) wastes) FTRs are the most attractive option, if (a) the FPPs are to maintain the present U235 once-through cycle; and (b) only low fusion power and low Q fusion reactors can be developed in the foreseeable near future. Scenario 2 (minor actinides and possibly long-lived FPs) FTRs are the best if (a) the FPPs can take the Pu isotopes; and (b) modest fusion power output (about 300 MW) and plasma Q (more than 1) are among the developmental goals for near-term experimental fusion reactors. ^{14}C, ^{60}Co, ^{63}Ni, and ^{204}Tl can be attractively produced in an experimental fusion reactor. These radioisotopes are produced through threshold reactions such as (n,p) and (n,α). ^{60}Co and ^{63}Ni products from fusion can have significantly higher specific activity than conventionally produced in fission reactors because the parent nuclide, ^{63}Cu, is from a different element. Because of the significance of nuclear waste transmutation as a solution to the long-term use of fission energy, Phase II will focus on the tasks relevant to the development of fusion transmutation reactors. Phase II will develop viable transmutation blankets (particularly Scenario 2 and 3 type) for the FTRs. It will specify the performance of tokamak FTRs facilitated with these blankets, identify cost-effective, near-term technology based small tokamak fusion reactors for achieving this performance, and examine the economic merits of these FTRs.

Anticipated Results/Potential Commercial Applications as described by the awardee: The economic aspect of the nuclear energy system with the planned FTR will depend strongly on the available fusion driver. A fusion driver with 50 to 300 MW fusion power, and break-even or better plasma Q, will be the most desirable for the development of FTRs to destroy all TRU and FP wastes. If successfully developed, the FTR will help to solve the environmental issues associated with the use of fission nuclear energy. The small fusion power reactor can also provide substantial amount of 14 MeV neutrons for nuclear technology testing for fusion energy development.

TECHNOLOGY FOR THE SUPERCONDUCTING SUPER COLLIDER

23

Radiation Damage Resistant Silicon for Particle Physics Detectors--IntraSpec, Inc., P.O. Box 4579, Oak Ridge, TN 37831; (615) 483-1859
Mr. John Walter, Principal Investigator
Mr. John Walter, Business Official
DOE Grant No. DE-FG05-92ER81436
Amount: $500,000

The use of silicon radiation detectors in particle physics research and other applications is restricted by their sensitivity to radiation damage. This is particularly true for the new generation of high energy colliders like the Superconducting Super Collider (SSC), where a high intensity of neutrons creates serious bulk damage problems. Most of the radiation damage research on these detectors has focused on studies of irradiated device behavior in detectors made from the same source of silicon and by similar oxide passivation techniques with little effort to date on improving the material. These studies have shown that neutron bulk damage creates excess leakage current noise, charge trapping resulting in signal deterioration, and changes in compensation level which change the electric field distribution in the device. This latter problem is perhaps the most serious, particularly for tracking devices and drift chambers. Changes in compensation level by uniformly distributed radiation damage can amplify the original fluctuations in compensation, thereby causing major spatial non-uniformities in resistivity and electric field strength. Aluminum (Al), which is an acceptor in its substitutional state, is known to passivate both point and cluster defects in silicon (Si), and it is posited that Al doping may be useful for improving the radiation hardness of Si detectors. Phase I demonstrated the feasibility of a unique method for uniformly introducing Al into silicon radiation damage studies. The spatial distribution of the Al introduction can be controlled to counteract compensation gradients in the starting material. Al doping may also allow a major cost reduction by allowing cheaper starting material. Phase II will use this material to study improvement in radiation hardness against bulk damage by fast neutrons.

Anticipated Results / Potential Commercial Applications as described by the awardee: Techniques which improve the radiation hardness of silicon detectors will have a major positive impact on their use in particle physics research, particularly if accompanied by a reduction in cost. This technique may have a major impact on other applications such as extraterrestrial solar cells and sensors for national defense.

24

Eddy-Current Nondestructive Testing Methods for On-Line Detection of Cable Manufacturing Defects--SE Systems, Inc., 26203 Production Avenue, Suite 10, Hayward, CA 94545; (510) 293-3000
Dr. Duane P. Johnson, Principal Investigator
Mr. Charles W. Roberts, Business Official
DOE Grant No. DE-FG03-92ER81457
Amount: $499,996

The overall objective of Phase I was to demonstrate the feasibility of using eddy-current technology for detecting manufacturing defects in superconducting cable, in a production environment. It was demonstrated in Phase I that eddy-current data from a single probe excited at 1 megahertz (MHz) and at 2.2 MHz can be used to detect all defects of importance on one narrow side. The objective of Phase II is to develop and demonstrate a prototype system capable of automatically inspecting superconducting cable as it is produced to detect broken and missing wire, cross-overs, sharp corners, and cold welds on both the narrow sides and the wide sides. Eddy-current probe assemblies, cable support fixtures, and test procedures will be developed for and demonstrated on 50 mm inner, 50 mm outer, and 40 mm outer superconducting cable. Phase II will utilize a state-of-the-art, commercial eddy-current instrument, smartEDDY 3.0, with custom designed probes, cable fixturing, and specially modified software. The smartEDDY 3.0 instrument has unique real-time digital data processing capabilities, data storage capabilities, and operating interfaces which make it ideally suited for this application. During a production run, the system will automatically store a defect report. The report will contain the production run ID number, the defect sequence number, the defect type, the defect location in centimeters from the beginning of the run, and the related eddy-current signal file name. Four surface probes and up to four instrument modules will be used. Two probes will be directed at inspection of the narrow sides of the cable, and two probes will be directed at the wide sides of the cable. The wide side probes will contain up to four sensing elements each to achieve 100% coverage.

Anticipated Results / Potential Commercial Applications as described by the awardee: Full commercialization of the inspection system will be done in Phase III. Inspection systems will be installed on production lines which manufacture cable for the Superconducting Super Collider (SSC). The SSC will require 13 production cabling machines, each with an inspection system. Additionally, magnet vendors may be required to perform acceptance testing on cable received from cable manufacturers. This would increase the number of inspection systems required by ten, for a total of 23.

25

Low-Cost Microstrip Detectors on Conductivity-Modified Polyimide--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Anton C. Greenwald, Principal Investigator
Mr. Richard S. Gregorio, Business Official
DOE Grant No. DE-FG02-92ER81463
Amount: $499,938

Detectors for particle tracking in the Superconducting Super Collider (SSC) must have extreme spatial (100 µm) and time (15 ns) resolution, and they must operate reliably in harsh radiation environments. Gas-microstrip chambers, a solid-state realization of traditional wire-chamber proportional detectors, offer a technology breakthrough to meet the particle tracking requirements of the SSC. In Phase I, fully operational microstrip chambers on ion implanted polyimide were built. These chambers produced well-resolved ^{55}Fe X-ray spectra at modest counting rates. They showed no degradation of gain or resolution after irradiation to 1 and 10 Mrad with ^{60}Co γ-rays, and gas gains as high as 7,000x were measured after 10 Mrad irradiation. In Phase II, operation in high count rate environments and realistic beam tests on existing accelerators will be demonstrated. Parametric experiments to improve process reliability and yield for small detectors will be performed, and technology to fabricate full-size (20 x 25 cm) gas microstrip detector (GMD) prototype panels will be developed and demonstrated.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will lead to low-cost, large area particle tracking detectors for the SSC intermediate angle spectrometer. These detectors will also provide a cost/performance breakthrough for high speed, high resolution digital detection in non-destructive testing and medical imaging. The process technology has applications to large scale use with conductive polymers, and these alternate applications are being developed separately.

HIGH ENERGY PHYSICS DATA PROCESSING AND DETECTOR INSTRUMENTATION

26

A Compact Optical Crossbar Switch Array for Large-Scale Photonic Networks--Physical Optics Corporation, 20600 Gramercy Place, Suite 103, Torrance, CA 90501; (310) 320-3088
Dr. Freddie Lin, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-92ER81304
Amount: $499,991

The large amounts of data generated in high energy physics experiments make necessary data acquisition systems or interconnect networks capable of handling very high data rates and large scale data switching. A novel optical crossbar switching technique for large scale data switching functions and high data communication bandwidth operations offers promise in these applications. In addition to compact size, light weight, and immunity to electromagnetic interference, the planned optical crossbar switching technique also has other unique characteristics, not simultaneously satisfied by any other optical crossbar switching technique. In Phase I, a preliminary design of the crossbar switching elements was completed, the feasibility of the planned optical switching concept was experimentally demonstrated, an array of switches was constructed, and the characteristics of the crossbar switch were estimated. The limitations of the optical switching concept in scaling up the array were also explored. Phase II will concentrate on product development of optical crossbar devices for both high energy physics experiments at DOE laboratories and various commercial photonic interconnect applications. The primary goal of the Phase II project is to develop working, large-scale optical crossbar switching arrays (>32 x 32; ideally 64 x 64) capable of high data transmission rate, high switching speed, and very low crosstalk. To achieve this goal, a system prototype demonstration, utilizing existing electronic systems for data sources and destinations, and optoelectronic transceiver boards as the interface between the digital electronics and optical components/devices will be constructed.

Anticipated Results / Potential Commercial Applications as described by the awardee: The large-scale optical crossbar switching arrays developed in this project can be immediately applied to high energy physics experiments at DOE laboratories, and can also provide a new family of products for commercial uses, such as in computer-to-computer networks, local area networks, and multiprocessor interconnect networks.

27

A Gallium Arsenide 16-Bit Sigma-Delta Analog-to-Digital Converter with a 100 Megahertz Conversion Rate--TechnoConcepts, Inc., 2363 Teller Road, Suite 118, Newbury Park, CA 91320; (805) 376-2336
Mr. Ronald M. Hickling, Principal Investigator
Mr. Michael G. Gunby, Business Official
DOE Grant No. DE-FG03-92ER81459
Amount: $499,732

High speed (20 - 200 MHz), high resolution (16 bits) analog to digital converters (ADCs) can perform an important role in the electronic instrumentation used in high energy physics. Gallium arsenide (GaAs) would seem to be an optimum technology for this application because of its inherent radiation tolerance. However, some of its limitations have prevented its use in ADCs thus far. During Phase I, the feasibility of using the high speed capabilities of GaAs to implement an oversampling converter with a 100 MHz conversion rate was investigated. Through the use of novel design techniques, a design for such a converter which could operate from the single 5.2V supply was developed. In Phase II, the primary technical objective is to achieve the capability to deliver working prototypes of the 16-bit sigma-delta converter integrated circuit. The activities will include fabricating test circuits for evaluating the design of key ADC building blocks, fabricating and characterizing a complete first order sigma-delta converter, developing a viable test methodology to verify 16-bit performance, and fabricating, characterizing, and delivering working prototypes of the 16-bit converter.

Anticipated Results / Potential Commercial Applications as described by the awardee: The results of this research can be used to develop high speed analog to digital converters in the 100-200 MHz speed regime for use in high energy physics research, commercial digital radio, high definition television (HDTV), and high speed instrumentation and telecommunications. The technology developed is applicable to high speed pulse code modulation (PCM) encoding as well.

TECHNOLOGY AND INSTRUMENTATION FOR HIGH ENERGY ACCELERATORS

28

Advanced Accelerators Based on Superconducting Band Gap Structures--AccSys Technology, Inc., 1177A Quarry Lane, Pleasanton, CA 94566; (510) 462-6949
Dr. James M. Potter, Principal Investigator
Mr. Curt W. Mason, Business Official
DOE Grant No. DE-FG03-92ER81274
Amount: $499,994

High energy linear accelerators generally utilize a series of suitably phased resonant cavities to effect the transfer of energy from microwave sources to the electron beam. The current design of the cavities is quite complex. This project is concerned with the demonstration of a Photonic Band Gap (PBG) resonator in a configuration suitable for the development of a high gradient (50 Mev/m) superconducting accelerator cavity. PBG resonators have unique properties which may overcome many of the limitations in present state-of-the-art accelerator cavity designs. The resonator is expected to have a very high quality factor (Q), defined as stored energy divided by dissipation per cycle. The very high Q resonance many prevail over a very large frequency range, so that higher order mode Q degradation is no longer a problem. In Phase I, numerical simulations of PBG structures were performed as a function of system parameters, with the purpose of establishing optimum configurations for accelerator applications (such as elimination of higher order modes and maximizing the ratio of the peak surface electric field to the average on-axis accelerating field). Many hundreds of cases were run. Experiments were initiated to develop a suitable means for coupling fields between adjacent resonators and for coupling radio frequency (RF) power into a PBG structure. Planning was completed for design and construction of a cryogenic test facility suitable for experimental evaluation of potential PBG configurations. In Phase II, the design will be finalized for the PBG resonator structure and accelerator cavity configuration. PBG resonators will be constructed. A test stand cryostat will be designed and fabricated, and the first phase of testing PBG resonators singly and in coupled units will be completed. The test system will then be shipped to a high energy test facility to complete the beam tests.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful demonstration of a high gradient accelerator structure using the Photonic Band Gap resonator concept will have a tremendous impact on the development of future linear colliders and on practical electron linacs for future medical applications. This simple, low-loss structure would allow one to build rather compact, efficient linacs for producing synchrotron radiation or high energy photons.

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A High-Current, Micro-Pulse Electron Source--FM Technologies, Inc., 10529-B Braddock Road, Fairfax, VA 22032; (703) 425-5111
Dr. Frederick M. Mako, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG05-92ER81447
Amount: $499,951

This project will demonstrate a high-current-density micro-pulse electron gun (MPG) concept that employs the resonant amplification of an electron current by secondary electron emission in a radio frequency (RF) cavity. Phase I studied this "multipacting" process in detail, including space charge and found the parameters necessary to make use of the phenomenon to produce a micro-pulsed electron beam. One wall of the cavity is made partially transparent to electrons but opaque to the input RF electric field. It was shown from self-consistent analytic theory and two-dimensional, fully relativistic, electromagnetic particle-in-cell (PIC) simulations that the current density scales with frequency cubed. The natural "bunching", or resonant phase selection of the particles gives rise to high current densities (20-5600 A/cm^2), high charge bunches (up to 100 nanocoulombs (nC)/bunch for a solid beam and up to 1000 nC for a hollow beam), and short pulses (36-3.5 picoseconds (ps)) for frequencies from 1.3 to 8 GHz. The beam pulse width was found to be typically 4.6% of the RF period. Beam extraction through the transparent wall was studied using a 2½ dimensional PIC code. Good beam transmission (52-85%) with low normalized emittance (9-18 mm-mrad) was achieved. The best normalized emittance per charge was 3 mm-mrad/nC. Tuning to the resonant parameters was shown to be very tolerant. Electrical breakdown was not a problem, and materials are available to satisfy the secondary emission yield requirements for this device. Applications are accelerator injectors and RF generation at a high harmonic of the fundamental frequency. Phase II experiments are planned at 1.3 GHz. A MPG will be built, and the resulting electron beam will be characterized. The key measurements to characterize the electron beam are: emittance, particle energy, current density, efficiency, and tuning sensitivity.

Anticipated Results / Potential Commercial Applications as described by the awardee: The micro-pulse gun avoids the difficulties associated with plasma cathodes, thermionic emitters, and field emission cathodes. Plasma cathodes cannot be operated at high repetition rate, nor can they sustain very long pulses without voltage collapse. Thermionic emitters are only good for low current densities (≤ 20 Amps/cm^2), and are easily contaminated. Field emission cathodes require a huge field (~4000 MV/m) for reasonable emission. (So far, laser initiated photo cathodes suffer from reliability issues in high electric fields.) This micro-pulse electron gun should provide a high peak power, multi-kiloampere, picosecond-long electron source which is suitable for many applications. Of particular interest are: high energy picosecond electron injectors for linear colliders, free electron lasers and high harmonic radio frequency (RF) generators for linear colliders, or super-power nanosecond radar.

30

A 17 Gigahertz Traveling Wave Relativistic Klystron for High Gradient Accelerators--Haimson Research Corporation, 4151 Middlefield Road, Suite 102, Palo Alto, CA 94303-4793; (415) 493-5012
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-92ER81284
Amount: $500,000

Electron accelerator linear collider studies continue to support earlier contentions that the most favorable choice of linac frequency is in the range of 10 to 20 gigahertz (GHz). There are advocates for working at the upper end of this range and with increasing values of beam pulse width, e.g. with pulse widths extending into the steady state regime, so that the charge per bunch and wake field effects can be reduced without loss of luminosity. Considerable interest exists in 17 GHz linear collider technology, and some research activities are in progress at MIT and in private laboratories interested in commercial applications of high frequency linacs. However, there are no practical sources of high radio frequency (RF) power presently available to support 17 GHz high gradient accelerator (HGA) research. (Linear collider RK development is at 14 GHz in Russia, and at 11.4 GHz in the USA and Japan.) Phase I investigated design approaches for the RF source and prepared layout and subassembly drawings for the Phase II high power RF test stand. It is the objective of Phase II to (1) design and fabricate a 17 GHz prototype traveling wave relativistic klystron having a 60 dB gain and an efficiency of > 48%, and (2) conduct high power, long pulse RF tests on this tube using an existing 580 kV, 60 MW video pulse power transmitter having a 1 µs pulse top characteristic ideally suited for demonstrating high quality RF performance. It is a further objective of Phase II to develop and fabricate an evacuated high power rectangular waveguide network comprising special WR62 components for precision measurement and absorption of the klystron output RF power - a necessary prerequisite for a carefully integrated overall test facility suitable for 17 GHz RK and HGA structure research. This 17 GHz prototype RF source, in direct combination with a 60 cm long HGA structure, will be capable of demonstrating electron beam energies in excess of 30 MeV. The long pulse specification of this tube will also make it a strong candidate for a 200 ns linear collider (4x) pulse compression system.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that Phase II will result in a compact, high power RF tube suitable (1) specifically for high gradient accelerator systems, with the capability of demonstrating high resolution beam performance using electron bunch widths of <1 ps, and (2) for commercial applications that would benefit from the substantially reduced size and weight of a 17 GHz linac configuration.

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An 11.4 Gigahertz 800 Megawatt Phase Stable Radio Frequency Generator--Haimson Research Corporation, 4151 Middlefield Road, Palo Alto, CA 94303-4793; (415) 493-5012
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-92ER81285
Amount: $498,520

This project investigates the means of providing an efficient, phase stable source of high radio frequency (RF) power suitable for high gradient 11.4 gigahertz (GHz) linear accelerator applications. Phase I was directed at (1) alleviating optics restrictions imposed by a high geometric emittance ($\beta\gamma\varepsilon \sim 1200\pi$ mm-m.radian) electron beam derived from a 5 MeV linear induction accelerator (LIA), (2) enhancing the efficiency of RF modulation of the relativistic beam, and (3) evaluating the means of generating RF power levels in excess of 400 MW from each of two traveling wave (TW) output structures without encountering E-field breakdown or pulse shortening due to higher order mode (HOM) instabilities. Phase I revealed that both matching of the high beam emittance and enhancing of the RF modulation efficiency could be achieved by imparting a relatively high transverse momentum to the 1000 A magnetically confined beam. This is achieved by using a novel high gain RF deflector and by arranging charge selection, for transmission through the subsequently located

TW structures, to occur during RF cycle intervals coinciding with reversal of the deflector longitudinal E-fields, i.e., when the energy spread imparted to the beam tends to zero. Additionally, TW structure analyses confirmed that output power levels in excess of 400 MW can be satisfactorily achieved by using low impedance, extended circuits to avoid RF breakdown, and by adopting recently developed powerful HOM suppression techniques to prevent pulse shortening. Phase II will design and fabricate a prototype version of the 800 MW, phase stable 11.4 GHz RF generator and will combine the beam centerline and the associated magnetic elements into a fully integrated compact assembly that can be conveniently installed in an existing Lawrence Livermore National Laboratory (LLNL) linac facility for high RF power testing and performance evaluation.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that Phase II will result in the availability of an 11.4 GHz, 800 MW phase stable RF generator that could either be integrated into a Two Beam Accelerator system for linear collider applications, or combined with a compact LIA to provide a self contained high RF power source for commercial applications.

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High Strength Mono- and Multi-filament High Temperature Superconductors for High Field Applications--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Leszek R. Motowidlo, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-92ER81461
Amount: $499,988

High temperature 2212 and 2223 Bismuth Strontium Calcium Copper Oxide (BSCCO) superconductors have been fabricated in practical conductor form and have demonstrated outstanding potential for low temperature (4-20°K) operation for device applications. Preliminary monocore tape designs have already shown critical current densities (J_cs) exceeding 2000 A/mm^2 at 4.2°K and magnetic fields up to 30 Tesla (T). Phase I demonstrated improved mechanical properties for 2212 multi-filament wire. A factor of two improvement in yield strength was demonstrated in Phase I. Both rectangular and round multi-filament 2212 wire were fabricated and tested in liquid helium at applied magnetic fields up to 12 T. Preliminary Phase I J_cs in the 2212 multifilament wire were 45,000 A/cm^2 at zero field and approximately 25,000 A/cm^2 at 12 T. In addition, a length over 500 meters of 2212 multi-filament wire was fabricated, demonstrating the feasibility of scale-up to kilometer lengths by the powder-in-tube method. Phase II will concentrate on development of a useful BSSCO multi-filament conductor, in lengths of 500 meters or greater, for magnetic field applications over 20 T with a J_c of approximately 500 A/mm^2 (at liquid helium temperature). In addition, Phase II will continue development of advanced designs, such as the high strength sheath ($Ag\text{-}Al_2O_3$) introduced in Phase I in place of pure silver. A conductor design will be developed that requires minimal ($Ag\text{-}Al_2O_3$) sheath, in order to reduce cost. Finally, novel ideas will be introduced and studied to develop improved pinning characteristics for higher temperature operation.

Anticipated Results / Potential Commercial Applications as described by the awardee: An improved technology base will be achieved for advanced power applications, utilizing high temperature superconductors at 4-20°K, for superconducting energy storage, motors, generators, and transmission lines. Energy storage should be particularly important, since power sags could cost electric power systems millions of dollars annually. In addition, high field Nuclear Magnetic Resonance (NMR) magnets in the 20-30 T range would become possible. Technology developed here will be useful in high energy physics accelerators and fusion energy systems.

33

Fabrication of Niobium-Aluminum Superconducting Strands Using Mechanical Alloying and Other Techniques--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-92ER81331
Amount: $499,962

The literature has shown that Nb_3Al exhibits higher critical magnetic field (H_{c2}), considerably greater strain tolerance, and better radiation resistance than niobium-tin (Nb_3Sn). Previous work on Nb_3Al has also clearly illustrated the potential for good current density at high field, but limitations in large scale production methods have prevented the material from becoming a viable conductor for high field magnets. Earlier work has shown that the finer state of subdivision on the Nb and Al components improves properties such as critical temperature (T_c), H_{c2}, and high field critical current (J_c). Phase I explored the feasibility of using mechanical alloying as a method of fabricating commercial lengths of material. The mechanically alloyed Nb+Al, or Nb/Al powders in two different states of subdivision, have been made into lengths of material. These were heat treated, and some of their properties were compared. Phase I showed that material made from mechanically alloyed powder in a finer state does show improved T_c, and values as high as 15.6°K were determined. Transport J_c measurements made on copper-clad monofilaments gave low values and showed weak link type behavior, suggestive of poor bonding. The overall objective of Phase II is to develop a commercial process for fabricating longer lengths of Nb_3Al conductor. The work will consist of two tasks: (1) a screening task in which the monofilamentary strand will be produced and the process parameters refined to make material with improved mechanical and superconducting properties, and (2) a follow-on task to produce multifilamentary strands. For the purpose of comparison, a second, relatively well established technique, the niobium tube method, will also be used to produce reference strands against which the properties of the "mechanically alloyed strands" can be compared.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will develop a larger scale production process for fabrication of Nb_3Al strands that have substantial critical current density at high fields. Such strands would allow construction of magnets with higher peak fields than can be presently made with Nb_3Sn. Structural requirements for these magnets (in terms of allowed strain) would also be relaxed considerably, due to the greater strain tolerance of Nb_3Al compared with Nb_3Sn. Nb_3Al also has somewhat less sensitivity to neutron radiation than does Nb_3Sn. Applications for such magnets include accelerator dipoles and quadrupoles and fusion research magnets.

34

Development and Testing of an Ion Probe for Tightly-Bunched Particle Beams--Mission Research Corporation, 8560 Cinderbed Road, Suite 700, Newington, VA 22122; (805) 963-8761
Dr. John A. Pasour, Principal Investigator
Mr. Scot R. Fries, Business Official
DOE Grant No. DE-FG03-92ER81297
Amount: $499,694

The project concerns an ion probe that employs a low-energy (≤30 keV), low-current (<1 µA) highly-focused stream of ions to diagnose a tightly-bunched relativistic charged particle beam. The probe ions are injected across the path of the relativistic beam and are deflected by the electromagnetic fields of the beam. The direction and magnitude of the deflection depends in a predictable way on the current, position, duration, and charge distribution of the high-energy beam. Consequently, by a suitable choice of operating parameters, the ion probe can resolve any or all of these parameters. Such a diagnostic can be implemented in a variety of accelerators, but interest is strongest in radio frequency (RF) bunched beams of very small diameter (<0.1 mm), because the usual techniques do not work well, if at all, in this regime. Furthermore, such beams are becoming increasingly crucial for such applications as particle colliders, synchrotron radiation sources, and short-wavelength free-electron lasers. In Phase I, extensive analyses of the ion probe were conducted, showing that the diagnostic has unprecedented capabilities to measure beam position, profile, charge, pulse length, and microstructure (asymmetries).

Because the mass and energy of the probe ions can be adjusted over a wide range, the probe is extremely flexible and can be used for a broad range of high-energy beams. Several new configurations were developed that could extend the performance to extremely small beams (<1 µm), critical components were identified, and a prototype system was designed. A simple analytic expression was derived that accurately predicts the deflection over much of the parameter space. During Phase II, the probe designed during Phase I will be built, tested, evaluated, and optimized. Testing of the probe will be performed at SLAC, which will provide beam time for this effort.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will lead to a practical, high-resolution, nonperturbing diagnostic for tightly bunched particle beams. It will allow the direct measurement of numerous beam parameters. It will be especially valuable for particle accelerators being used or developed for the most demanding applications, such as particle colliders, free-electron lasers, and synchrotron light sources. Because it is capable of continuous use, it could be used to monitor emittance growth and beam oscillations in cyclic accelerators and storage rings. Some of the technology developed here will also be applicable to such areas as semiconductor processing and pulsed-power and plasma physics research.

35

A Harmonic Converter to Produce High-Power 10-30 Gigahertz Microwaves--OMEGA-P, Inc., 2008 Yale Station, New Haven, CT 06520; (203) 432-4201
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG05-92ER81338
Amount: $500,000

This project addresses the need for new radiofrequency (RF) sources for the next generation electron-positron collider. In Phase I, theory and computation indicated that the fifth harmonic conversion efficiency can be over 50%, and that most of the residual beam energy can be recovered in a one- stage depressed collector. Candidate designs for demonstration proof-of-principle experiments were also selected based on the use of an available 20 megawatt, 2.85 gigahertz (GHz) klystron source. In Phase II, experiments are planned to assess the theoretical predictions of low power flow into competing modes, and of the weak influence of the expected levels of spread in beam particle guiding center and axial momentum. Means of increasing the direct conversion efficiency will be explored. Theory for the acceleration and conversion processes will be extended to account for beam space charge and for harmonic conversion in grooved waveguides. This will demonstrate the harmonic conversion from spatiotemporal modulation on an electron beam produced by cyclotron autoresonance acceleration.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful demonstration of efficient, high-power harmonic conversion in the range of 10-30 GHz would provide an economically appealing source of microwaves to drive a teravolt (TeV)-level electron-positron collider, since use would be made of existing SLAC klystrons and supporting systems. Other potential uses of efficient high-power harmonic converters include heating and control of plasmas for fusion energy, millimeter wave radars, and applications in deep space communications.

ACCELERATOR TECHNOLOGY FOR NUCLEAR PHYSICS

36

An All-Solid-State Laser Source for Production of Polarized Electrons for the Continuous Electron Beam Accelerator Facility--Lightwave Electronics Corporation, 1161 San Antonio Road, Mountain View, CA 94043; (415) 962-0755
Dr. Thomas R. Steele, Principal Investigator
Dr. Richard W. Wallace, Business Official
DOE Grant No. DE-FG03-92ER81291
Amount: $499,846

This project addresses the need for a complete diode-pumped, all-solid-state tunable laser system suitable for generating polarized electrons at the Continuous Electron Beam Accelerator Facility (CEBAF). Phase I investigated a number of all-solid-state laser approaches that could be used in a second generation source for CEBAF. This effort has identified a clearly preferred approach: the use of chromium (Cr)-doped laser crystals which can be directly pumped by 670 nanometer (nm) "red" diode lasers. Phase II will pursue detailed development of this approach. The first step will be to develop a 670 nm diode pump module that will combine the output of ten diode lasers yield a bright pump source with approximately 2 watts of optical power. This source will be used to develop Cr-doped, tunable, mode-locked lasers suitable for generating polarized electrons for CEBAF. High repetition rate mode-locking in the range of 100-1500 megahertz (MHz) will be investigated. The aim is to produce pulsewidths of 10-100 picoseconds and average powers of 100-300 milliwatts. This all-solid-state laser system will be compact, efficient, long-lived, and reliable. These characteristics will make this laser a cost effective, superior replacement for the first generation source to be used at CEBAF.

Anticipated Results/Potential Commercial Applications as described by the awardee: A complete diode-pumped, all-solid-state tunable laser system suitable for generating polarized electrons at CEBAF will be developed. This laser will have many other scientific and industrial applications, such as in seeding high-peak power (terawatt) amplifier systems, spectroscopy, probing of semiconductors, atmospheric monitoring, and evaluation of linear and nonlinear optical materials. No diode-pumped, all-solid-state tunable source is currently commercially available. The 670 nm pump module by itself will also find commercial application as a replacement for small-frame krypton-ion lasers.

ROBOTICS AND REMOTE OPERATIONS IN CIVILIAN NUCLEAR REACTOR FACILITIES

37

Star Motor: An Inherently High-Torque, Low-Speed Piezoelectric Motor for Modular Robotics--Bonneville Scientific, Inc., 918 East 900 South, Salt Lake City, UT 84105; (801) 359-0402
Dr. Allen R. Grahn, Principal Investigator
Ms. Josephine M. Grahn, Business Official
DOE Grant No. DE-FG02-92ER81439
Amount: $500,000

The use of advanced robotic systems in nuclear power plants can reduce both the outage duration and radiation exposure of personnel. Mission flexibility and modularity are key parameters for these robotic systems. Star Motor is a piezoelectric motor which inherently produces high torque at low speeds and has the potential of achieving energy densities 40 times greater than their electromagnetic motors. Furthermore, Star Motors have a very high degree of modularity. Phase I established the feasibility of the Star Motor concept by (1) designing and fabricating both a very simple one-pole motor and a six-pole prototype Star Motor, (2) developing suitable motor drive electronics, (3) evaluating motor performance, and (4) developing a more complete rotary and linear motor design. Phase II will (1) develop a light-weight but powerful parallel-jaw gripper and a twelve-pole Star Motor, (2) develop energy-efficient drive electronics, (3) evaluate motor performance, and (4) test motor operation in nuclear reactor environments.

Anticipated Results/Potential Commercial Applications as described by the awardee: The motor technology developed in this project will have wide-spread application in Government and civilian robotic applications because of its low-speed, high-torque characteristics and high energy density. These same features will make Star Motor attractive for use in prosthetic limbs and actuators in remotely operated vehicles. The micro-stepping capability of Star Motor can be exploited in devices for micropositioning, ranging in size from miniature robotic grippers to large x-y tables.

38

Implementation of a Three-Dimensional Mapping/Inspection System for Inside-Tank or Containment Areas--Cybernet Systems Corporation, 1919 Green Road, Suite B-101, Ann Arbor, MI 48105-2554; (313) 668-2567
Dr. Charles J. Jacobus, Principal Investigator
Mrs. Heidi N. Jacobus, Business Official
DOE Grant No. DE-FG02-92ER81391
Amount: $500,000

The Department of Energy (DOE) and commercial manufacturing firms have entered into numerous agreements with the Environmental Protection Agency and State natural resources departments to meet or exceed current environmental standards for storage of nuclear wastes. Virtually all current legislation mandates frequent visual inspection of waste storage facilities and tankage, which augments routine leakage detection/monitoring, to assure that hazardous materials are not being released into the environment. Most new tankage for nuclear wastes provides for double containment. However, the inner containment barriers must receive routine 100% visual inspection to verify that no leaks or corrosion problems are developing. At present, no commercial sensors or systems provide the means to perform these inspections. The system to be developed and tested in this project will solve several near term inspection needs. Phase I demonstrated a technology which improves the current process for inspection of tank and containment areas. It makes possible the acquisition of three dimensional and color imagery from a sensor which is easily radiation hardened, can be configured to fit through a small diameter opening (4 inches in diameter or larger in the initial version), and includes an integral robotic positioning subsystem so that the sensor can achieve the full area coverage currently required. In Phase II, a radiation hardened version of the Phase I prototype and its robotic positioner will be developed. Telerobotic control of the sensor/positioning system will be implemented. The controller and sensor/positioner will be tested by using it to perform inspections of tankage at Oak Ridge National Laboratory and at other DOE facilities. Various automated defect and corrosion algorithms will be investigated.

Anticipated Results / Potential Commercial Applications as described by the awardee: Cleanup and inspection must be done inside nuclear containment chambers and within large chemical, petroleum, and waste disposal/holding tanks. This operational environment precludes safe human presence, demanding autonomous means for sensing, mapping, and navigating of robotics mechanisms for cleanup and inspection. Current environmental protection agreements require periodically performed 100% inspection of all containment chambers and tankage, to assure that no leakage into the ground water system is occurring. Analysis indicates that a reusable tank inspection and characterization system will easily pay for itself in 3 to 6 months, if routine inspection requirements are put into full force. Routine inspection of these hazardous sites will improve the environment.

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A Steam Generator Upper Bundle Intertube Inspection and Maintenance Robot--Foster-Miller, Inc., 350 Second Avenue, Waltham, MA 02154-1196; (617) 890-3200
Mr. J. Timothy Lovett, Principal Investigator
Mr. Ross R. Olander, Business Official
DOE Grant No. DE-FG02-92ER81370
Amount: $500,000

Steam generator repairs cost the U.S. nuclear power industry approximately $200 million in 1991. Major tube plugging and sleeving programs and steam generator replacements are becoming increasingly common. Tube deposits also reduce thermal efficiency. Despite the strong economic incentives to remove deposits from steam generator tubes, no satisfactory technique currently exists. High pressure water lancing is effective between the tube sheet and the fist tube support plate of the steam generator, where handholes provide direct access. However, the lack of handholes in the upper bundle area, precludes the use of this existing technology in that region. An upper bundle intertube inspection and maintenance system offers a safe, cost-effective approach to removing these deposits and extending steam generator life. Phase I evaluated the feasibility of an upper bundle intertube maintenance and inspection system, whose primary function is deposit removal by high pressure water jets. This evaluation provided the following critical answers: (1) The upper bundle intertube region can be accessed through existing handholes in the shell and flow slots in the several tube support plates. (2) Support hydraulic energy can be delivered within the tube bundle to remove the deposits within an acceptable time period. (3) Either a rigid lance or a flexible lance can provide intertube access; either can be packaged to fit through the handhole and the flow slots. (4) Remaining technical risk with the planned upper bundle intertube system is associated primarily with the intertube access system and the subsystem that supports and indexes it between tube rows. Phase II will address these areas of technical risk by single nozzle testing and mock up testing to permit optimization of the intertube access system. A prototype intertube access system, lateral support system, and indexing system will be constructed and demonstrated. A design for the complete system will be prepared based upon the results of the testing of these prototype components.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will provide a new maintenance capability to the U.S. and foreign commercial nuclear power industry. A system will become available for inspecting and removing deposits from steam generator secondary sides using high-pressure water jets. Removal of secondary side deposits will permit recovery of lost thermal performance, reduce corrosion damage to tubes, delay costly steam generator replacement, and obviate chemical cleaning with its large quantities of hazardous waste. The use of high-pressure water jets for deposit removal is a safe, cost-effective, environmentally friendly maintenance option.

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Environmental Hardening of a Mobile-Manipulator Robotic System for Nuclear Environments--REMOTEC, Inc., 114 Union Valley Road, Oak Ridge, TN 37830; (615) 483-0228
Mr. John R. White, Principal Investigator
Mr. Howard W. Harvey, Business Official
DOE Grant No. DE-FG05-92ER81437
Amount: $499,978

This project will involve testing and design to harden environmentally a commercially available mobile robot. In Phase I, the active components of this robot were classified, and the expected total-dose hardness of each component was estimated. Component manufacturers were contacted to determine whether radiation hardness and temperature data were available for each component. This baseline of information was used to prioritize the testing of components and replacement item identification. The initial evaluation has indicated that the Phase II objective of a megarad hardened control system should be achievable. The most critical components, for which there were no historical data, were selected for early baseline testing. Components will be evaluated for stability in harsh environmental conditions, and corrective action will be taken to replace or protect susceptible items. By using available off-the-shelf replacements to the maximum extent possible, the system costs will be kept to a minimum. The primary focal point of the project is the computerized control system of the robot. The microprocessor, along with associated circuitry, relays, amplifiers, presents the most difficult challenges in environmental hardening. In Phase II, the design of the entire robot will be evaluated, and hardened components will be used in place of identified weak items. Module-hardened control components will be tested and modified if necessary. The robot will be assembled from components, and cold-tested. The entire vehicle will be tested in a gamma ray irradiation environmental chamber at the University of Florida. This effort will provide nuclear facilities with substantially improved capabilities to perform tasks in these harsh environments.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will produce a commercially available radiation hardened mobile robot. It will provide operators of nuclear facilities with a vehicle to perform routine and accidental functions in areas inaccessible to personnel. Additionally, specific components, i.e., computerized control systems, will be adaptable to other remote equipment such as bridge cranes, master-slave manipulators, and hot cell process equipment.

TECHNOLOGY TO SUPPORT AND IMPROVE NUCLEAR FUEL CYCLE PROCESSES

41

A Dual Liquid Level Measurement System for Pyrochemical Processing of Nuclear Fuels--DELTA M Corporation, 525 Warehouse Road, Oak Ridge, TN 37830; (615) 483-1569
Mr. R. W. McCulloch, Principal Investigator
Mr. A. D. White, Business Official
DOE Grant No. DE-FG05-92ER81434
Amount: $500,000

This project addresses the need for a level measurement system for application to the pyroprocessing of nuclear fuel, as required in the Integral Fast Reactor Program at Argonne National Laboratory (ANL). To this end, proof-of-principle tests in Phase I have verified that both single and dual thermal differential sensors can achieve the sensitivity and accuracy demanded by the applications. Phase II will bring the thermal differential level measurement techique from proof-of-principle established in Phase I to validation of the instrument for the pyroprocessing application. This includes definition of specifications for the simultaneous determination of a liquid metal/molten salt interface and a molten salt/gas interface at a temperature of 500°C or higher, in an environment typical of nuclear fuel reprocessing. The thermal- based level measurement system will be simple in concept, relatively low in cost, rugged, easily insertable and removable from the system, safe in operation, and have an accuracy of better than 3.2 mm (0.125 in.). The design of the Phase II system is supported by technology developed at Oak Ridge National Laboratory during the 1970s and early 1980s for out-of-reactor thermal-hydraulic safety and reactor core design instrumentation. The first year of Phase II will include fabrication and evaluation of a second generation dual sensing probe, encompassing design and fabrication of a high temperature test apparatus, fabrication and testing of a digital-based data acquisition and analysis system, and long term testing of the probes and associated electronics to establish probe stability and measurement reproducibility specifications. Based on these results, a probe system will be fabricated, calibrated, and delivered to ANL for demonstration tests. A final design, along with the pertinent documentation, will then be completed. A separate task will investigate additional probe applications using the established technology, to identify major potential markets, define marketing strategies for industrial commercialization, and identify potential Phase III participants.

Anticipated Results/Potential Commercial Applications as described by the awardee: The end result of this project will be the development and delivery to ANL of a high temperature, rugged, reliable, safe, and cost-effective dual liquid level measurement system for pyrochemical processing of nuclear fuels. Potential commercial applications include level measurements of liquid metals and molten salts in the energy and metal production areas, in the chemical industry, at research institutions, and for leak detection in nuclear/chemical waste storage tanks located at various nuclear facilities throughout the United States.

TECHNOLOGY FOR SPACE NUCLEAR PROPULSION AND POWER

42

High Energy Density Power Sources: A Combination of New Semiconductors and Radionuclides--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Charles C. Blatchley, Principal Investigator
Mr. Patrick N. McDonnell, Business Official
DOE Grant No. DE-FG02-92ER81385
Amount: $499,462

Phase I showed that there are a number of possible semiconductor materials which could be used to make long life (high energy density), radionuclide-voltaic electric power cells. Power sources with energy densities more than a thousand times better than the best chemical batteries are feasible. The common lead-acid battery covers the region from 1-10 W-h/kg. Radioisotope powered voltaic cells can reach levels of 10^6 W-h/kg. Analyses and tests have indicated that, for very long life and good power density, thin films of indium phosphide (InP) grown on silicon (Si) is the best semiconductor material for use with alpha emitting radioisotopes. Direct conversion of alpha energy also appears promising with materials such as copper indium diselenide (CIS). Gallium arsenide (GaAs) has advantages for beta energy conversion. At elevated temperatures this material has shown an ability to anneal the damage as fast as it is produced. In Phase II, cell design will be optimized and prototype alpha and beta voltaic cells will be produced. Two types of devices are targeted for prototyping: GaAs converters combined with beta emitters and organometallic chemical vapor deposited (MOCVD)-grown InP on Si combined with alpha emitters

Anticipated Results/Potential Commercial Applications as described by the awardee: A series of high energy density radioisotope powered voltaic cells will result from this project. They are expected to provide opportunities for using a wide variety of radioisotopes generated in nuclear reactors, thereby alleviating the shortage of elements such as Pu-238. Applications include space power, implantable defribillators, and heart assist devices.

ENRICHMENT OF URANIUM FOR CIVILIAN NUCLEAR POWER REACTORS

43

Damage and Power Sensors for High Power Laser Delivery Fibers Using Low-Cost Fluorescent Optical Fibers--Physical Optics Corporation, 20600 Gramercy Place, Suite 103, Torrance, CA 90501; (310) 320-3088
Dr. Robert Lieberman, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-92ER81303
Amount: $499,999

In Phase I it was demonstrated that plastic optical fibers with fluorescent cores can be used in a low-cost, non-obtrusive scheme to monitor leakage from optical power delivery fibers for breakage. It was also demonstrated that the fluorescent fiber approach can be used both to determine precisely where fiber damage has occurred, and to make an inexpensive, reliable power meter for undamaged fibers. Phase II will continue this work, specifically tailoring both power-measurement and damage-detection experiments to the specific needs of the Lawrence Livermore National Laboratory (LLNL) Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) project. The project will design, develop, deliver, and field-test a complete system capable of monitoring power levels, and detecting damage, in the large-core silica fibers used to carry power from copper vapor lasers to dye lasers in the AVLIS test facility. Two methods will be investigated: a distributed approach that uses a fluorescent fiber running the whole length of the power fiber to monitor spatially averaged energy flux, and a fiber-end approach that uses a highly-doped fluorescent fiber to monitor the power delivered at the output end of the fiber carrying the laser light. During the project, custom fluorescent fibers created specifically for use at copper vapor laser wavelengths will be cabled and connected in intimate contact with actual power delivery fibers. These fibers will be connected to a custom-built detector array interface and tested for accuracy, reliability, sensitivity, and longevity in a series of laboratory experiments. Finally, the fully characterized system will be delivered to LLNL, where field tests will be conducted. The results of these tests will be used in a cost-benefit analysis to verify that this simple, yet very effective system will be useful for monitoring power delivery fibers in full-scale AVLIS production facilities.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of this project would result in the installation of a demonstration model laser delivery fiber power and damage monitoring system that could find immediate practical use at LLNL. Once field tested, the system could be expanded to cover all power fibers at the AVLIS facility, and could be used to greatly enhance efficiency and safety in future large-scale AVLIS production facilities. Potential spinoff applications include medical fiber monitoring, and non-invasive monitoring of communications fibers.

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Beam Diagnostic Modules Utilizing Diffractive Beam Samplers--Rochester Photonics Corporation, 330 Clay Road, Rochester, NY 14623; (716) 272-3010
Dr. John P. Bowen, Principal Investigator
Dr. Dean Faklis, Business Official
DOE Grant No. DE-FG02-92ER81466
Amount: $499,982

Implementation of an atomic vapor laser isotope separation (AVLIS) production plant will require the use of arrays of multiple beam diagnostic units for control of the beams. Recent innovations in diffractive optics technology have shown that diffractive optical elements offer the potential to reduce significantly the size, weight, and cost of a variety of optical systems which currently utilize refractive and/or reflective components. In Phase I, over fifteen design scenarios that address various diagnostic functions were investigated. As a result of recent developments in fabrication technology, the diffractive systems investigated could be characterized by a short overall length. The issues of polarization sensitivity and small zone spacings for diffractive surfaces were also investigated. Phase I also included a complete analysis of techniques for the fabrication of the diffractive components. In order to maintain low absorption and scatter, the profile must be etched into polished, high-grade fused silica. To demonstrate proof-of-concept early in Phase I, several diffractive devices that implement multiple beam shaping functions were implemented. These proof-of-concept experiments demonstrated the applicability of the technology to the Uranium-AVLIS application. In Phase II, diagnostic modules utilizing diffractive elements combined with refractive optics will be assembled. The designs will be analyzed for performance over the range of operation. The final tests will be performed in a high-power beam line at Lawrence Livermore National Laboratory (LLNL). Work with LLNL researchers will also investigate new concepts for the application of diffractive optics, and will consider the best manner for impelmenting the use of this technology by the Uranium-AVLIS production plant.

Anticipated Results/Potential Commercial Applications as described by the awardee: Optical beam diagnostic modules based on this project can assist the implementation of laser isotope separation processes. This work may have additional applications for high-power beam sampling, inertial confinement fusion, commercial laser optics, optical testing, and optical communications.

ADVANCED COAL UTILIZATION

45

A Low Cost, Flexible, Magnetohydrodynamic Generator Test Facility--Busek Company, Inc., 19 Kearney Road, Needham, MA 02194; (617) 449-3929
Dr. V. J. Hruby, Principal Investigator
Mr. J. Budny, Business Official
DOE Grant No. DE-FG02-92ER81362
Amount: $499,677

The goal of this project is to construct a low cost magnetohydrodynamic (MHD) facility for the testing of disk generators. A gas heater was designed in Phase I. It will be capable of providing 3000°K working fluid at 10 atm pressure. It will be able to operate with Ar, He, H_2, and N_2 to perform closed-cycle and simulated open-cycle MHD experiments. Disk loft calculations were performed using an existing disk generator numerical model. Extensive analysis of several magnet options were performed to find the lowest cost magnet and power supply system. A suitable 7.5 Tesla superconducting magnet was identified. Detailed analysis of the major components confirmed the viability of each component and hence the viability of the complete facility which will be the first in the U.S. to operate with a superconducting magnet. In Phase II, the gas heater will be designed, constructed, and tested. The 7.5 Tesla superconducting magnet will be procured and installed in the test facility design, and the disk generator design will be refined, reflecting the final component specifications. The first generator to be tested will be a helium-driven disk with a maximum thermal power input of 47 MW_{th}. This facility will be the first in the U.S. to operate with a superconducting magnet.

Anticipated Results / Potential Commercial Applications as described by the awardee: The facility will be capable of low-cost, fast turn-around MHD generator testing. The disk offers high performance in small sizes when driven by an inert working fluid which will intensify utility interest. The facility can be used for investigating nuclear and chemically fueled generators of interest to DOE, NASA, and DOD.

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A Light Metal Fueled Nonequilibrium Plasma Generator--ERC, Inc., 205 Research Park Drive, P.O. Box 417, Tullahoma, TN 37388; (615) 455-9915
Dr. Y. C. L. Susan Wu, Principal Investigator
Dr. Y. C. L. Susan Wu, Business Official
DOE Grant No. DE-FG05-92ER81435
Amount: $499,942

The nonequilibrium plasma generator (NPG) concept burns high energy metals (e.g., aluminum), mixing the metal oxide products with an inert gas stream to produce a plasma capable of sustaining nonequilibrium ionization in a magnetohydrodynamic (MHD) generator. Light metal combustion produces extremely high flame temperature. When inert gas (argon) is mixed with combustion metal oxides and expanded to MHD generator inlet conditions, the metal oxides will condense in minute particles yielding a clean, extremely hot plasma that can drive the nonequilibrium MHD process. The NPG concept can produce a steady state source of higher temperature nonequilibrium plasma than is achievable with current technology, which will stabilize the MHD nonequilibrium ionization process and lend higher efficiency and power density to the MHD disk generator. Phase I included scientific and engineering analyses of NPG, and identified aluminum as the preferred fuel and argon as the best working fluid. Powdered aluminum flow experiments were conducted, and a conceptual design for an aluminum powder feed system was conceived; this system will require developmental testing in Phase II. The principal objective of Phase II is to design, fabricate, and test a laboratory scale NPG. The experimental NPG will burn fine aluminum powder in pure oxygen and vitiate argon to create an argon plasma. A series of proof-of-principle experiments will be conducted with the NPG test apparatus. The first tests in Phase II will be conducted to determine the operating conditions and NPG geometry required for optimizing the aluminum combustion and argon mixing processes. The concluding tests will demonstrate production of a nonequilibrium plasma with the NPG concept. The experimental program will be used to establish a design data base on the NPG that can be used to scale up the concept to commercial size. Phase II will simultaneously be directed at conceptual study of using the NPG in a pulse power, nonequilibrium MHD disk generator system. This application is chosen for near term development. Other possible applications for the NPG will be explored in Phase II including use of the NPG in closed cycle commercial power MHD power generation. A potential Phase III program will be planned to build a large scale aluminum-argon NPG, integrate it with an existing MHD disk generator, and conduct first-of-a-kind demonstrations of pulse power from a nonequilibrium MHD disk generator system.

Anticipated Results / Potential Commercial Applications as described by the awardee: The light metal NPG will provide a compact device capable of producing a high energy plasma or stream that can be used in MHD research and parallel technologies. It has potential as a product for research and commercial field applications. The NPG can support central power MHD research through replacement of the large regenerative heat exchangers needed for nonequilibrium ionization MHD disk generator experiments. The NPG is a device that could directly drive an MHD disk generator, making this concept viable for pulse power MHD. The NPG concept is applicable to research in other MHD disciplines, e.g., MHD propulsion and in ground tests of gas-cooled nuclear reactor concepts for MHD power or rocket propulsion.

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A Dechlorination System for Magnetohydrodynamic Spent Seed--HMJ Corporation, 10400 Connecticut Avenue, Suite 404, Kensington, MD 20895-3910; (301) 946-1586
Dr. William D. Jackson, Principal Investigator
Dr. William D. Jackson, Business Official
DOE Grant No. DE-FG02-92ER81355
Amount: $500,000

The open cycle magnetohydrodynamic (MHD) coal-fired power plants have the potential to provide substantial improvements in the thermal efficiency of electric power generation, but several key engineering issues must be resolved before these improvements can be achieved. One of these is efficient processing of the seed added to the combustion products to render them electrically conducting. This seed has to be reprocessed and, in the process, the conditions exist for chloride buildup. The chlorides resulting from the spent seed material must be removed, or their concentration reduced, to control their buildup in the recycled seed. Further, the system in which this is done must be capable of integration into the MHD/steam combined cycle without adverse effect on its performance. To dechlorinate the spent seed without losing potassium, the University of Tennessee Space Institute (UTSI) has developed an anion exchange resin-based concept. This concept is simple, uses mild operating conditions, and is based on existing technology of water softening. It offers a potentially attractive method to carry out simultaneously the desulphurization and the dechlorination of MHD spent seed at an overall cost significantly lower than the process currently being developed. Phase I resulted in the selection of two suitable resins and a preliminary demonstration of the feasibility of the process. In Phase II, system analysis will be conducted to identify the preferred operating conditions of the seed reprocessing system, a process demonstration unit will be built and operated on the Coal-Fired Flow Facility, and engineering data on its operation will be obtained. These data will be used to undertake the conceptual design of an MHD plant incorporating the UTSI process. The process is particularly suited to high sulphur coal. To facilitate comparison with conceptual designs, the Scholz Plant has been selected to provide the MHD/steam interface for the integrated conceptual design. The project will include the development of a data base designed for prototype and commercial scale plants.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of the project will provide a technically attractive option to simultaneously dechlorinate and desulfurize the MHD spent seed material at an overall cost considerably lower than what can be expected for the approach currently under development. It will resolve a critical technical issue and greatly improve the prospects for acceptance of MHD technology by the electric industry and its suppliers.

ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY FOR FOSSIL ENERGY

48

Conversion of Atmospheric Fluidized Bed Combustion Residue and Waste Oily Emulsion to Cement Plant Fuel and Feed Stock--CEMCOM Research Associates, Inc., 1919 Halethorpe Farms Road, Baltimore, MD 21227; (410) 247-0012
Dr. Sean Wise, Principal Investigator
Mr. William E. Hanford, Jr., Business Official
DOE Grant No. DE-FG05-92ER81351
Amount: $499,204

In Phase I, it was shown that the residual lime contained in the residues from atmospheric fludized bed combustion systems can be used in the treatment of oil/water emulsions, creating a waste water that can be discharged into a sanitary sewer, and a non-hazardous oily residue that can be used as a fuel for a cement kiln. Phase II will optimize this process in order to produce an aqueous discharge which is better than could be obtained with lime and also a higher quality fuel for cement kiln application. The optimized process will be demonstrated on pilot plant scale using two ashes: a high reactivity AFBC bed ash and a low reactivity AFBC bed ash. The oily residue by-product from these separations will be used in test burns in a cement kiln, to study its effectiveness as a fuel and its influence on the environmental emissions from the plant. The quality of the clinker will be measured after each of the test burns. Information related to adapting the process to other systems will be developed, and other water treatment applications will also be investigated.

Anticipated Results / Potential Commercial Applications as described by the awardee: The benefits from the use of this technology include reduced volumes of solid waste (from both ash and oily residues), cost savings associated with the reduced solid waste disposal, and energy savings for cement manufacture (the waste can be used to fuel a cement kiln). The process should be suitable for application to appropriate non-hazardous waste treatment, and for application, without significant capital investment, to treatment operations currently using lime.

49

A Sorbent Injection and Filtration Process for Hydrogen Sulfide Removal from Hot Gas--
CeraMem Corporation, 12 Clematis Avenue, Waltham, MA 02154; (617) 899-0467
Dr. Daryl L. Roberts, Principal Investigator
Dr. Robert L. Goldsmith, Business Official
DOE Grant No. DE-FG02-92ER81364
Amount: $500,000

This project addresses the development of an innovative, attrition-tolerant process for removing H_2S from hot coal gas streams. The process consists of injecting finely-divided sorbent (e.g., 5 µm to 20 µm particle size) into the hot, sulfur-containing coal gas followed by removal of the spent sorbent in a compact ceramic filter. Because of the ability of the highly compact, low-cost filter to capture even sub-micron particles and to be regenerated by backpulsing at temperatures up to 1800° F, the fine sorbent particles and any smaller particles resulting from attrition or vapor phase sulfidation reactions can be handled conveniently in the process. In Phase I, the technical feasibility of this process was demonstrated with three sorbent chemistries and three sorbent particle sizes in a small-scale drop tube furnace under simulated coal gas conditions. In general, H_2S removal efficiencies were greater than 99% with a one second duct residence time and with sorbent/H_2S stoichiometric ratios as low as 1.15. In addition, the spent sorbent particles were captured quantitatively (>99.9%). The principal objective of Phase II is to develop a more extensive understanding of the fine sorbent duct injection process for H_2S sorption and sorbent regeneration, primarily through experimentation at the bench scale. Measurements will be made of H_2S uptake and sorbent regeneration rates in a flow reactor under a range of practical operating conditions, to answer key questions about the operability of the process and to establish the rate controlling steps in each part of the process. During these rate studies, issues affecting sorbent lifetime, such as vaporization of metals and formation of sulfates, will be examined. Selected sorbents will be subjected to life tests (repeated cycling through uptake and regeneration) to determine the rate and extent of any sorbent deactivation processes. In the experimental test program, favorable operating ranges will be identified. A computation model of the uptake and regeneration reactors will be devised on the basis of fundamental mass transfer principles and the experimental data. Then, a process model, incorporating mass and energy balances and approximate equipment sizes, will be used to make an economic assessment of the process operation on a large scale (e.g. 400 MW (electric) integrated gasification combined cycle plant).

Anticipated Results / Potential Commercial Applications as described by the awardee: A major obstacle to commercialization of coal gasification processes is the lack of a proven process for removal of H_2S from product gas. Successful development of the duct injection process could significantly increase reliability and reduce costs for such H_2S removal.

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Coal-Gas Multiple Contaminant Polishing--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 792-1460
Dr. A. Pigeaud, Principal Investigator
Dr. H. C. Maru, Business Official
DOE Grant No. DE-FG05-92ER81330
Amount: $500,000

There are a significant number of contaminating and toxic vapors present at low levels in coal gas, even after hot-gas desulfurization with zinc ferrite on titanate. Phase I was successful in showing that a novel gas polishing method removes at least five of the seven coal gas trace contaminants (considered significantly harmful) by absorbing them in a high temperature liquid sorbent material (molten tin or a tin-containing liquid alloy). Four metallic vapors and a metalloid compound were shown to be absorbed in the polishing liquid (zinc, cadmium, lead, mercury, and arsenic hydride). The removal of these contaminants is estimated, based on Phase I results, to be adequate to very good. Two of the contaminant species (chlorine and sulfur) were not polished by this method, and will have to be removed separately. Phase II will include tasks to: (1) determine from multicomponent thermochemical equilibrium the theoretical sorption levels of important contaminants and study the prospects for thermal regeneration of the pure sorbent material, (2) use experimental studies of the equilibrium activities of individual trace species in the planned high temperature liquid sorption system to attempt confirmation of the results from the previous task, and (3) design, build, and operate a laboratory sorption reactor to simulate the process of counterflow gas/liquid contacting of contaminated fuel gas with the sorbent system. Pametric studies will lead to the initial analytical data for the kinetics of the process.

Anticipated Results / Potential Commercial Applications as described by the awardee: U.S. energy production is expected to rely increasingly on its domestic coal sources. Thus the U.S. economy will stand to benefit greatly from an inexpensive method of hot-polishing, coal-derived fuel gas. Inexpensive total cleaning of this fuel gas will always be required for the complete protection of various kinds of downstream equipment. Accordingly ultimate gas polishing will be extremely important to all end-users of gasified coal, and will help to protect the environment. Very clean emissions and solid wastes after polishing will also greatly enhance the prospects for rapid commercialization of new and advanced integrated gasifier fuel cells, as well as of more conventional integrated gasifier combined cycle systems (coal-gasification/electricity-producing).

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Durable, Low Cost Ceramic Materials for Use in Hot Gas Filtration Equipment--Industrial Filter and Pump Manufacturing Company, 5900 West Ogden Avenue, Cicero, IL 60650; (708) 656-7800
Mr. Paul Eggerstedt, Principal Investigator
Mr. Paul Eggerstedt, Business Official
DOE Grant No. DE-FG02-92ER81349
Amount: $493,071

Ceramic candle filtration is an attractive technology for particulate removal at high temperature. Due to their simple and cost effective design, temperature capability, and high filtration efficiency, ceramic candles are one of the few clean up technologies which can consistently meet gas turbine manufacturers' inlet particulate requirements and Clean Air Act mandates. Unfortunately, traditional "hard" ceramic candles made from granular silicon carbide can be prone to failure from physical and thermal shock and chemical attack; also, these candles tend to be expensive and, because of their weight, present internal filter design problems. Unlike "hard" candles, vacuum formed chopped ceramic fiber (VFCCF) filter candles offer excellent physical and thermal shock resistance at a low cost, using existing vacuum forming technology. The VFCCF "skeleton" can be further treated with colloidal materials to tailor particle retentivity, strength, and corrosion resistance to suit a given application. The products are significantly lighter in weight than their "hard" ceramic counterparts. With their combined strength, high temperature capability, and low thermal expansion, VFCCF materials are ideal for both filter elements and internal filter hardware. Phase I showed that the strength characteristics of VFCCF materials responded extremely well to the infusion of colloidal ceramic oxide solutions. It was possible to increase the strength of prototypical VFCCF tubesheet specimens eight-fold. By variation in colloidal solution application techniques and curing methods, it was possible to increase VFCCF filter candle strength in critical flange and end cap areas with a minimal decrease in candle permeability. Phase II will perfect the best colloidal application and treatment methods from Phase I, and evaluate the effects of long term alkali exposure at high temperature on the strength characteristics of the most promising specimens. Additionally, efforts will be made to investigate mullite and Saffil VFCCF filter components, longer fiber lengths, and an integrally formed candle flange.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase II will show how well these treated materials tolerate temperature and vapor-phase alkali species, on a long-term basis. Increased durability, higher temperature capability, and lower installed and replacement costs of these novel materials will promote commercial acceptance of ceramic candle filter technology and increase overall coal utilization process efficiency and reliability.

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Power Conditioning for Efficient, Effective Removal of Nitrogen Oxides, Sulfur Oxides, and Toxic Materials from Effluent Gases--Integrated Applied Physics, Inc., 261 North San Gabriel Boulevard, P.O. Box 70166, Pasadena, CA 91117-7166; (818) 449-0039
Dr. George F. Kirkman, Principal Investigator
Ms. Roberta Gundersen, Business Official
DOE Grant No. DE-FG03-92ER81287
Amount: $499,919

Pulsed corona discharge, silent discharge, and electron beam processing of effluent gases have been shown to remove effectively a variety of hazardous air pollutants. Recent experiments have demonstrated removal of NO_x and SO_2 from coal burning industrial plants and diesel engines. A key requirement for implementing this process is efficiently and reliably producing high voltage high current pulses with fast risetime and short pulse length at high repetition rates. Ways of producing such pulses have long been known; but since they have been developed for the exacting requirements of radar and particle accelerators, they have been too expensive and delicate to use in industrial gas cleaning applications. Workers have been forced to use old, spark-gap technology in order to obtain the necessary life and ruggedness at reasonable expense. This project will develop a high voltage power modulator for efficiently driving a non-thermal plasma treatment reactor suitable for a demonstration of these processes. The modulator is based on an innovation in switching technology and novel modulator concepts demonstrated in Phase I, and will use a low-cost, high efficiency approach to generating the necessary pulses. This approach will feature both a novel transformer which allows the modulator to produce high current, high voltage pulses with a minimum voltage stress on the switch, and the new back-lighted thyratron-superemissive cathode (BLT-SEC) switch which operates with a superemissive cathode allowing very high currents in a small package with a long lifetime. The switch has demonstrated repetition rates and lifetime an order of magnitude larger than spark gap switches operating at comparable currents. Phase I demonstrated this switch in a novel modulator producing 100 kV output pulses with 80% efficiency using a switch voltage of 25-30 kV. Phase II will produce a modulator giving 100 kV, 10 kA, 200 nsec output pulses with 50 nsec risetime at 300 Hz. The system will have >85% efficiency and a long life. Applications will result in the design of a pilot plant demonstration that could be carried out in Phase III.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful completion of this project, demonstrating a significant improvement in pulse modulator efficiency, will result in low cost, reliable pulsed power systems for pulsed plasma treatment of coal burning plant flue gases for efficient emission control. The innovation of the BLT-SEC switch combined with novel modulator techniques will make this approach to emission control economically and technically feasible. The systems developed will have applications other than large electrical and industrial plants, including residential fossil fuel fired systems, and diesel engine emission reduction.

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An Intrinsically Safe, Laser-Based Optical Diagnostic for Hot Gas Stream Cleanup--Southwest Sciences, Inc., 1570 Pacheco Street, Suite E-11, Santa Fe, NM 87501; (505) 984-1322
Dr. David S. Bomse, Principal Investigator
Dr. Alan C. Stanton, Business Official
DOE Grant No. DE-FG03-92ER81404
Amount: $499,403

This project will lead to the development of diode-laser-based instruments providing exceptional sensitivity and selectivity for the real time detection of key gases in harsh, high temperature, and high pressure environments. The instruments are targeted at the needs of coal-fueled energy conversion systems requiring hot gas cleanup processes to reduce emissions. This approach uses reliable, relatively inexpensive, solid state diode lasers that are compatible with fiber optics, and will be incorporated into fully automated, safe instruments capable of continuous, on-line operation. Phase I demonstrated the effectiveness of the technology by measuring trace ammonia concentrations using a diode laser operating near 1.5 µm. Detection limits using one spectral line that is free of interference from water and carbon dioxide are 3.7 ppm-m (300° K and 1 atm.) and 54 ppm-m (1000° K and 5 atm). In Phase II, a prototype instrument will be built for analysis of ammonia and hydrogen cyanide in hot gas streams. This prototype will be tested and evaluated in experiments performed at the Morgantown Energy Technology Center. In situ and extractive gas sampling will be compared. Success in Phase II is expected to lead to instruments also capable of detecting hydrogen sulfide, hydrogen chloride, hydrogen fluoride, nitrogen dioxide, nitrogen trioxide, carbon monoxide, and carbon dioxide.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase II will culminate in the development of intrinsically safe sensors for monitoring hot gas cleanup processes. The laser-based technique, as applied to the detection of ammonia, offers significant advantages over currently available technology because this approach is not impaired by the presence of other gases such as nitric oxide and sulfur dioxide.

ADVANCED TECHNOLOGY FOR THE RECOVERY OF NATURAL GAS

54

A Process for Sweetening Sour Gas by Direct Thermolysis of Hydrogen Sulfide--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. David J. Edlund, Principal Investigator
Dr. Rod Ray, Business Official
DOE Grant No. DE-FG03-92ER81419
Amount: $499,982

About 25% of the natural gas produced in the U.S. contains excessive amounts of H_2S. Current methods for treating this sour natural gas (e.g., amine scrubbing coupled with flaring or the Claus process, and liquid redox systems) produce environmentally objectionable byproducts. As increasingly stringent environmental regulations are legislated and enforced, current gas-sweetening technology will become inadequate for economically utilizing the nations' sour-gas reserves--estimated to be 135 trillion cubic feet. Continued development of a membrane-reactor-based process to sweeten sour natural gas without releasing sulfur compounds (such as SO_x) to the atmosphere or producing other toxic or polluting byproducts appears promising. The membrane-reactor process will be energy- and cost-efficient relative to currently used processes. The membrane reactor achieves high efficiency in the direct conversion of H_2S in the sour-gas feed to elemental sulfur and H_2, by employing a platinum-coated, H_2-permeable metal membrane that catalyzes the decomposition of H_2S and simultaneously separates H_2 as it is produced. In Phase I, it was demonstrated that the H_2S thermolysis reaction catalyzed by the membrane surface was very rapid, and that the rate of conversion of H_2S to H_2 and elemental sulfur (beyond the equilibrium value) was proportional to the rate of H_2 removal via the metal membrane. Tests at realistic operating conditions showed that the formation of coke and other byproducts on the membrane surface was insignificant. Phase II is directed at increasing H_2 flux by reducing the thickness of the Pt coating on the feed surface of the membrane. Using a prototype reactor that utilizes this high-flux membrane, a synthetic sour natural gas feed (at 1000 psi) will be treated by reducing H_2S from an initial concentration of about 0.5% down to ≤4 ppm (pipeline specifications).

Anticipated Results / Potential Commercial Applications as described by the awardee: The membrane-reactor process is expected to sweeten sour natural gas without producing SO_x (a leading cause of acid rain), toxic metal and sulfide wastes, or other pollutants. Processing costs equal to or less than that of current methods for treating sour gas are projected. Projected processing costs for the membrane-reactor process are ≤$0.20/1000 standard cubic foot for streams containing ≤0.5% H_2S (about 80% of the H_2S-bearing gas currently in production in the U.S.). In addition, the process could also find application in treating H_2S in refinery streams--replacing the current reliance on the Claus process and associated tail-gas clean-up systems.

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Remote Leak Survey Capability for Natural Gas Transport Storage and Distribution Systems--Deacon Research, 2440 Embarcadero Way, Palo Alto, CA 94303; 415-493-6100
Dr. Anthony O'Keefe, Principal Investigator
Ms. Olive Lee, Business Official
DOE Grant No. DE-FG03-92ER81282
Amount: $500,000

The detection of natural gas and coal mine methane leakage is important for both worker safety as well as for environmental considerations. The accepted techniques for the detection of such leaks are based upon slow air sniffing systems which detect the major constituent of natural gas (methane) by chemical means. While such techniques are sensitive, they are slow and must be employed in the immediate vicinity of the suspected leak. Remote optical detection of methane has been demonstrated, but such systems have been too complicated for field use. Phase I developed a small and rugged remote optical sensor for the detection of dilute gaseous methane in air which utilizes a proprietary stabilization scheme. The approach is considerably less complicated than other schemes, such as distributed feedback frequency stabilization, and will be inexpensive enough to manufacture for several commercial areas. The sensitivity, ruggedness, and simplicity of this approach was demonstrated in Phase I. Phase II will develop a prototype system design suitable for field testing for performance and regulatory certification.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will develop a commercial detector of methane gas leaks. The device will be used in the transportation, storage, and distribution phases of gas handling to prevent explosions, to reduce the impact of greenhouse gas emissions by early detection of methane sources, and as safety instrumentation in coal mining.

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Electrochemical Natural Gas Reduction to Alcohols--Eltron Research, Inc., 2830 Wilderness Place, Boulder, CO 80301-5455; (303) 440-8008
Dr. Anthony F. Sammells, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG02-92ER81344
Amount: $499,994

This project aims towards the development of advanced electrolytic technology for the purpose of promoting methane hydroxylation at practical rates, selectivities, and efficiencies leading to the synthesis of commercially significant alcohols. Phase I identified advanced electrocatalyst and catalyst sites which were incorporated into gas diffusion electrodes, demonstrating high activity towards promoting initial oxygen reduction, from a methane/oxygen reactant gas mixture. Subsequent proton abstraction from the methane intermediate was found to be followed by reaction to yield methanol and ethanol. Experimental conditions were identified which gave high efficiencies for this process and provided a technical foundation for optimization. Methanol synthesis rates observed during Phase I using electrodes which were not yet optimized, were up to three orders of magnitude greater than those for conventional heterogeneous methanol synthesis. Phase II will include (1) preparing selected electrocatalysts and catalysts, (2) performing an in depth electrochemical study of electrocatalyst and catalyst optimization for improved selective methane hydroxylation, (3) incorporating preferred dispersed electrocatalysts and catalysts into gas diffusion electrodes, compatible for application with aqueous and polymer electrolyte-based electrolytic technology, and (4) fabrication and performance testing of electrolytic stack technology. The application of mature technology for methane hydroxylation leading to alcohol synthesis will be expected to proceed with higher selectivity, efficiency, and rate than for related heterogeneous reactions leading to the same reaction products.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful completion of this overall program will result in the development of technology for achieving methane activation under ambient or near ambient conditions, leading to the synthesis of condensed species such as methanol. This technology would provide an option for lowering costs associated with methane conversion to methanol and, consequently, will be of value to the chemical feedstock industry. A plentiful supply of low cost methanol could then be used as a feedstock for gasoline synthesis on an industrial scale, thereby reducing dependency on foreign energy sources.

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Reinterpretation of Existing Wellbore Log Data Using Neural-Based Pattern Recognition Processes--Jason Associates Corporation, 1500 West Canal Court, Suite 400, Littleton, CO 80120; (303) 798-8032
Mr. Curtis L. Morgan, Principal Investigator
Ms. Jill Haynie, Business Official
DOE Grant No. DE-FG03-92ER81315
Amount: $472,392

A significant portion of known gas reserves is contained within heterogeneous reservoirs for which well logging, using current analytical techniques, often can only provide information of a qualitative type. This is due to the indeterminate nature of geologic signal processing, combined with the inherent limitation of utilizing mechanistic approaches to analyze the interrelationships of multiple signals in complex geologic formations. Hydrocarbon Signature Logs (HSLs) identify producing zones with a greater degree of accuracy than can be derived using conventional wellbore analysis. This can substantially increase the hydrocarbon discovery rate for obscure reservoirs. HSLs are created using a proprietary process termed PROWLS, (Pattern for Wellbore Log Suites). PROWLS is based upon an emergent pattern recognition technology called neural computing, that has been developed primarily through Department of Defense sponsored research to address the problems of identifying military targets in difficult environments. Phase I successfully adapted this technology so that it can be used to identify oil-producing zones in a well, using a suite of conventional wellbore logs. Proof of concept was initially demonstrated using the Silurian Interlake formation, which is an Upper Interlake Subgroup of the central Williston Basin, that produced oil and gas from sequences of thinly interbedded peritidal dolomites and calcareous dolomites. On the Nesson Anticline, the Silurian interval is recognized as an area with a high potential for bypassed production because of the extreme difficulty of identifying pay zones using conventional log analysis. HSLs developed for wells in this formation identified producing intervals to a high degree, that were not achievable with conventional analysis. Phase I demonstrated that PROWLS can reliably estimate production of tight gas sands based upon patterns contained within the log suites. Further, PROWLS accurately identified all of the dry wells within the study field. HSLs were produced that showed definitive signatures indicating downhole porosity and permeability of the producing sand. Maps were produced that identified producing trends for the study field. Phase II will define process capabilities and limitations. Procedures for model verification and validation will be designed. The PROWLS process will be imbedded into an existing commercial well log software system. Extensive demonstration cases will be developed to show system capabilities.

Anticipated Results / Potential Commercial Applications as described by the awardee: PROWLS will be a software product that will allow oil and gas professionals, with no prior experience in neural computing, to take advantage of this state-of-the-art pattern recognition technology. Innovative applications of this technology will facilitate additional gas production from depleted or nearly depleted fields, enhance development of new production, and create new reserves through discovery of bypassed pay of oil and gas.

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An Advanced Liquid Membrane System for Natural Gas Purification--LSR Technologies, Inc.,
898 Main Street, Acton, MA 01720; (508) 635-0123
Dr. ZhenWu Lin, Principal Investigator
Mr. S. Ronald Wysk, Business Official
DOE Grant No. DE-FG02-92ER81372
Amount: $500,000

The cost associated with contaminant removal from natural gas is considerable. Impurities such as H_2S, CO_2, N_2, moisture, and natural gas liquids must be removed in order for the gas to be suitable for pipeline transport. H_2S removal and recovery in particular can involve costly processing steps, due to the low selectivity of this contaminant by chemical solvents, which also have an affinity for CO_2. This project will develop a novel Moving Liquid Membrane System (MLMS) for the selective removal of hydrogen sulfide. The MLMS combines absorption and regeneration in the same processing unit. Its design utilizes a large surface area for high mass transfer in a compact control volume. Also, the liquid circulation rate is much lower than that of conventional absorption systems. Phase I has shown that the MLMS has the ability to produce very high H_2S permeability and H_2S/CO_2 selectivity. The bench-scale membrane apparatus has also proven to be completely stable with no evidence of membrane dryout or degradation. The concept needs further refinement of its design through additional laboratory and pilot-scale testing. Phase II will focus on further testing for H_2S removal using simulant feed gases. It is also important that new gas processing technology be brought to the field to validate its operability with real gas. Therefore, a larger pilot scale unit will be constructed to evaluate the long-term operability of the system with industrial gas. A key aspect of the research will be to bring the technology to the demonstration stage.

Anticipated Results / Potential Commercial Applications as described by the awardee: The MLMS is well-suited to treating gases with significant H_2S concentration (up to the percent range), especially when the CO_2 to H_2S concentration ratio is high. Projections from the gas industry indicate that new reserves will likely be smaller, of lower quality, and at remote locations. The simplicity and performance of the MLMS will make it an attractive choice in these applications.

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An Airborne Imaging Sensor for the Detection of Natural Gas Emissions--OPHIR Corporation, 10184 West Belleview Avenue, Suite 200, Littleton, CO 80127; (303) 933-2200
Dr. Loren D. Nelson, Principal Investigator
Mr. Donald Rottner, Business Official
DOE Grant No. DE-FG03-92ER81318
Amount: $499,900

This project will develop an airborne imaging sensor for the detection, monitoring, and quantitative analysis of atmospheric trace gas emissions. An airborne system would provide cost-effective surveys of natural gas production and distribution facilities, and would enable rapid data analysis and identification of the locations and extent of natural gas leaks. The sensor will provide false color images, indicating natural gas concentration, incorporated onto standard video images of the observed terrain. Thus, the location of gas emission sources, the extent of gas distribution through the atmosphere, and the total emitted gas quantity could be determined. The detection limit of this sensor is very low, on the order of 3 ppb. Performance appraisals indicate a system detection capability of 56 ppb methane and 13 ppb ethane, for monitoring changes in evenly-dispersed gases, while providing gas concentration images from an airborne platform moving at 100 miles per hour. Phase I included target gas species selection (both methane and ethane), sensor spectral region determination, Phase II sensor hardware selection and preliminary sensor design for Phase II, and mathematical modeling of the radiometric detection process to estimate sensor performance. Phase I confirmed that an airborne imaging sensor can be fabricated and would provide excellent detection sensitivity. Phase II will concentrate on the final design, fabrication, laboratory calibration, and airborne flight testing of the technology.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will provide an imaging sensor for the evaluation of greenhouse gas and natural gas emission. This technology holds considerable commercial potential. U.S. Government agencies will require such a system to evaluate greenhouse emissions in the near future. The private sector could benefit from a cost-effective sensor designed to detect gas leaks. In addition, this sensor could provide a cost-effective, airborne geochemical prospecting technique for naturally emitting petroleum reservoirs.

COAL-BASED ALTERNATIVE FUELS TECHNOLOGY

60

Compliance Advisor: Development of Software Tools for Fuel Switching/Blending to Meet SO_2 Regulations at Coal-Fired Power Plants--PSI Technology Company, 20 New England Business Center, Andover, MA 01810; (508) 689-0003
Dr. Shin G. Kang, Principal Investigator
Dr. Anthony N. Pirri, Business Official
DOE Grant No. DE-FG02-92ER81376
Amount: $500,000

This project will develop a protocol and model for fuel switching/blending to meet SO_2 regulations at coal-fired power plants. Utilities are adopting coal switching and blending in order to meet more stringent SO_2 emissions regulations. However, most utility companies lack experience in burning "non-design" coals, and are in need of guidelines to help them assess the impact of different coals and blends on the performance of their boilers. The model will allow utilities to select and blend coals which meet SO_2 regulations while minimizing boiler operational problems such as deposition or increased opacity. The model will reveal rational blending strategies by considering: (1) the beneficial effects of flyash capturing SO_2, and (2) the detrimental effects of flyash causing operational problems such as slagging and poor electrostatic precipitator (ESP) performance. The software product is based on the successful results obtained from Phase I as well as the grantee's experience in boiler slagging. Through systematic experimental studies in Phase I, it was found that significant in-situ capture of SO_2 is possible with calcium in coals and coal blends. The grantee has developed a model that can predict the SO_2 reductions from knowledge of ash chemical composition. In Phase II, there will be further study on the impact of coal switching and blending on the performance of existing boilers, development of rules for evaluating the performances of coals and coal blends, and assessment of the impact of in-situ sulfur capture by ash on slagging and ESP performance. The technical approach will include laboratory experiments to develop submodels for sulfation and SO_3 formation, incorporation of existing slagging and ESP submodels, and selected field testing to validate the overall model. Also, these models will be combined with PC-based, user-friendly slagging models developed previously to produce the end commercial product, a PC-based tool to evaluate SO_2 capture by ash and its impact on slagging and ESP performance.

Anticipated Results/Potential Commercial Applications as described by the awardee: The software product will be able to predict quantitatively the SO_2 emission levels of given coals and the deposition potential of blends. The software will provide to electric utilities a tool for intelligent selection and blending strategies. This will allow relatively inexpensive coals to be utilized, while meeting the SO_2 regulations and minimizing operational problems.

61

A Torsional Rheometer for Measuring the Properties of Coal and Coal-Water Slurries--Viscoustech, 2836 Ridge Drive, Allison Park, PA 15101-2511; (412) 486-1087
Dr. Luoyi Tao, Principal Investigator
Dr. Chandrika Rajagopal, Business Official
DOE Grant No. DE-FG02-92ER81429
Amount: $492,100

Solids and slurries handling processes and equipment are quite inefficient when compared to equipment that handle liquids and gases. This is primarily due to a lack of a clear understanding of the behavior of granular materials and slurries. In Phase I, a torsional rheometer was designed. The use of this rheometer will lead to a better characterization of the properties of granular materials and slurries. In Phase II, this rheometer will be fabricated and calibrated. The rheometer has a cup and plate assembly between which the material is placed. The cup is fixed while the plate is capable of rotating and/or oscillating torsionally about their common axis. The cup and plate are removable. The unique rheometer design also allows the use of either sintered porous disks or impervious disks for the cup and plate. The sintered porous disk design allows the fluidization of granular materials, and the impervious disk design allows the measurement of the properties of slurries. A dynamometer on the shaft of the bottom cup assembly measures the three dynamic components and the dynamic reaction torque experienced by the bottom cup. A rotating dynamometer mounted on the shaft of the top plate also provides the three dynamic force components and the dynamic torque. The spacing between the plates and the motion of the motor is also controlled by the computer. The data from the top and bottom dynamometer are correlated to determine the material moduli, using a computer data acquisition system and software. A rheometer will be manufactured that can measure the properties of granular materials, using a computer data acquisition system and software.

Anticipated Results/Potential Commercial Applications as described by the awardee: The use of this rheometer will result in better designs for solids handling equipment like bins, silos, hoppers, chutes, hydrocyclones, agricultural grain dryers and combustors, and in the transportation of solids and fluidized beds. Since the inefficient performance of these various devices has contributed to inefficient plants and sometimes their failure, better rheological characterization of slurries should lead to tremendous savings. It should also lead to significant savings in other industries involved in surface finishing, and make possible measurement of all the material moduli of blood, needed for design of the artificial heart.

REDUCTION AND CONVERSION OF INDUSTRIAL WASTES

62

A Novel Energy-Efficient Membrane System for the Recovery of Volatile Organic Contaminants from Industrial Process Gases--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. Scott B. McCray, Principal Investigator
Dr. Rod Ray, Business Official
DOE Grant No. DE-FG03-92ER81420
Amount: $499,931

The removal of volatile organic contaminants (VOCs) from industrial process gases constitutes a significant industrial and environmental problem worldwide. Recovery of VOCs is advantageous, both for environmental reasons and for process-efficiency reasons, but conventional technologies (and "first-generation" membrane technologies) for VOC removal have drawbacks that limit their use for this application (e.g., limitations on the percentage of VOCs that can be removed, excessive energy consumption, and inability to withstand exposure to the feed-stream components and harsh operating conditions required.) The overall goal of this project is to develop a membrane-based system for recovering VOCs that avoids the drawbacks of conventional unit processes and first-generation membrane technology. This new membrane-based VOC-recovery system will be applicable to a wide range of VOCs and will be capable of reducing the concentration of VOCs from very high concentrations to the 20-ppm level or below, recovering the VOCs in liquid form for disposal or reuse. In Phase I, system feasibility was demonstrated. Hollow-fiber membranes from new solvent-resistant polymers were successfully developed, incorporated into high-efficiency modules, and tested. The modules effectively reduced the concentration of acetone in nitrogen feed streams from 42,000 ppm to 20 ppm and maintained performance in long-term (350-hour) tests. An economic analysis showed that the planned system offers major cost advantages over competing technologies. The focus of Phase II is to (1) develop hollow-fiber membranes from one or two alternative solvent-resistant polymers, (2) optimize the VOC-selective coatings used on the hollow-fiber membranes, (3) scale up the membrane modules to a size that will allow field tests and pilot tests at a reasonable scale, and (4) design and fabricate a prototype system for use in field tests.

Anticipated Results / Potential Commercial Applications as described by the awardee: The commercial applications for this membrane-based VOC-recovery system are numerous. It will be applicable to a wide range of VOCs and will be capable of reducing VOC levels from very high values down to about 20 ppm or less. The technology would have applications in the chemical-process, petrochemical, and pharmaceutical industries. Initially, the technology would be commercialized for "end of pipe" applications, and later would be integrated into existing processes as a "waste reduction" technology.

BATTERIES FOR TRANSPORTATION

63

High Cation Mobility Lithium Polymer Batteries--Covalent Associates, Inc., 10 State Street, Woburn, MA 01801; (617) 938-1140
Dr. Larry A. Dominey, Principal Investigator
Dr. Victor R. Koch, Business Official
DOE Grant No. DE-FG05-92ER81365
Amount: $499,968

The successful development of high energy density, rechargeable lithium (Li) polymer electrolyte-based batteries requires that two issues be addressed: (1) the charge and mass transfer properties at the Li/electrolyte interface, and (2) the concurrent maximization of lithium ion mobility along with the immobilization of the anion. Resolving these issues should lead to cells with improved performance, particularly with regard to rate capability. In Phase I, polymer electrolytes containing novel lithiated ionomers were prepared. These were blended with Li ion solvating polymers and plasticizers, and the conductivities of the polymer electrolytes were measured. The addition of Li methide, $LiC(SO_2CF_3)_3$, to the electrolyte solutions further increased the ionic conductivity. The anodic stability of electrolytes containing Li methide was found to be superior to that of all other electrolytes evaluated. In Phase II, polymer electrolyte conductivity and mechanical properties will be optimized. The electrolyte will also be fabricated so as to have a high Li ion transference number and good anodic stability. Initial full cell studies in laboratory cells will provide valuable data for the design and building of spiral-wound full cells.

Anticipated Results / Potential Commercial Applications as described by the awardee: Safe ambient-temperature rechargeable Li and Li-ion polymer electrolyte batteries which allow commercially practical discharge rates will find widespread use in cellular phones, laptop computers, camcorders, and large scale applications such as electric vehicles and load leveling.

ADVANCED INDUSTRIAL SENSORS, INSTRUMENTATION, AND CONTROL SYSTEMS

64

A Real-Time X-Ray Detector--Advanced Technology Materials, Inc., 7 Commerce Drive, Danbury, CT 06810; (203) 794-1100
Mr. David Kurtz, Principal Investigator
Mr. Daniel P. Sharkey, Business Official
DOE Grant No. DE-FG05-92ER81327
Amount: $500,000

In spite of the enormous growth in thin film processes and products, in-situ process monitors for chemical and physical vapor deposition have been limited to the acquisition of basic process conditions such as temperature, pressure, and flow rates. In Phase I, an in-situ x-ray diffraction (XRD) monitor for real time microstructural analysis of chemically vapor deposited metal and metal oxide films was demonstrated. The XRD device, a position sensitive scintillation detector

(PSSD), was modified for use in a reactor environment to measure simultaneously critical film parameters including phase composition, degree of crystallinity, texture (preferred orientation), thickness, and residual stress. In contrast to traditional x-ray diffraction systems, the PSSD system is compact, requires no scanning, and, most importantly, has very rapid sampling times. The Phase I experiments were designed to quickly determine the feasibility of in-situ thin film growth monitoring. By limiting deposition temperatures to 550°C, minimal changes to the primary detector components were required. Phase II will demonstrate the viability of the in-situ PSSD system in real world applications. Integration of robust on-line sensors that can measure critical microstructural characteristics will enable thin film manufacturing strategies that incorporate sensors and active feed-back controls into intelligent processing equipment. Intelligent processing of materials will reduce costs and improve quality for a broad spectrum of products ranging from semiconductors to steel.

Anticipated Results / Potential Commercial Applications as described by the awardee: A commercial, in-situ x-ray diffraction device would be applicable to process monitoring, analysis, and control for numerous manufacturing technologies. Major impacts on quality and yield will lead to rapid industry acceptance of this device in thin film coating, metal forming, semiconductor processing, and non-destructive evaluation (NDE) applications.

65

Development of an Oxygen Sensor for Continuous Measurement in Molten Steel--Defense Research Technologies, Inc., 354 Hungerford Drive, Rockville, MD 20850; (301) 762-3077
Mr. R. Michael Phillippi, Principal Investigator
Dr. Tadeusz M. Drzewiecki, Business Official
DOE Grant No. DE-FG05-92ER81354
Amount: $499,587

The last decade has witnessed an increasing push toward super-clean steel, that demands that oxygen content be very low, less than 20 parts per million. The goal of this project is to develop commercially viable, continuously reading, solid oxide, galvanic cell oxygen sensors for duty in liquid steel. Phase I demonstrated innovative thermal shock protection technology for fragile zirconia sensing elements and provided insights regarding the long term stability of the reference material and the parasitic thermocouple effects of the various dissimilar materials in the sensor loop. The problem of continuous temperature measurement was resolved by the development of a thermowell that can withstand contact with molten steel. Some of that thermowell technology has been applied to the oxygen sensor. The susceptibility of the heavy duty zirconia cell to thermal shock was resolved, allowing long term operation. The approach to the thermal shock problem used novel and innovative ablative techniques that moderated the rate of temperature increase of the zirconia cell during immersion into the molten steel. During Phase I, there was operation for over 5½ hours with two separate devices in the continuous caster tundish at the Bethlehem Steel, Sparrows Point facility. This was preceded by several hours of dummy probe tests to validate sensor protection schemes. Depletion of the oxygen content of the chrome-oxide reference material was detected, and a reverse biasing voltage scheme has been proposed to prevent oxygen ion transfer by effectively establishing an equal and opposite emf wherein the effort (emf) to prevent ion movement becomes the sensor output. The development of the current sensor has been based on operation in the relatively benign environment of the tundish. It has been demonstrated that a continuously reading oxygen sensor in the tundish can be cost effective in limiting the quantity of steel that is routinely downgraded when heats are cast without a ladle shroud, thereby producing significant savings. In Phase II, a commercially viable oxygen sensor will be developed for tundish operation and to provide sufficient field testing to demonstrate its reliability, reproducibility, and accuracy. The basis for an oxygen sensor that can be mounted in a ladle argon injection lance will also be developed. This is important because the major impact of continuous oxygen sensing is in the ladle treatment process, where closed loop control of the oxygen content can lead to significant reductions in treatment time, as well as to improved low oxygen content steels. Several prototype oxygen sensors will be built and tested in the ladle treatment facility of an industrial steel plant.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that at the end of Phase II a commercially-viable oxygen sensor for use in a continuous caster tundish will be available for production. A commitment has been received from Bethlehem Steel to implement the sensors at its Sparrows Point facility to limit the automatic downgrading of steel. It is also expected that a rigorous basis will be established for the development of a sensor system for ladle operation. Since ladle treatment is where the oxygen content is controlled, such a sensor would have a major impact on the steelmaking process, and give U.S. manufacturers a competitive edge over foreign competition.

66

An Inexpensive Miniature Positioning Instrument for Intelligent Control Systems--IntelliSense Corporation, 93 Massachusetts Avenue, Suite 300, Boston, MA 02115; (617) 266-6222
Dr. Fariborz Maseeh, Principal Investigator
Dr. Fariborz Maseeh, Business Official
DOE Grant No. DE-FG02-92ER81371
Amount: $500,000

Conventional inertial navigation systems have many potential uses beyond aircraft and spacecraft applications, but are seldom utilized because of their high cost, large size, and heavy weight. By dramatically lowering the cost, a miniature smart positioning and navigation system promises to be popular in industrial and medical applications as well as in the avionics markets. The novel aspect of the miniature positioning system developed in this project is the use of silicon microsensors with on-chip functionality such as solid-state micromachined gyroscopes. Micromachined gyroscopes have several advantages over common rotating-mass gyroscopes, including longer service life, far smaller size, large dynamic range, and much lower cost. In Phase I, the technical feasibility of a miniature monolithic gyroscope for an intelligent control system was established, the integration issues of gyroscopes in a positioning system were investigated, a prototype fabrication process for the sensor was determined, and a manufacturing cost analysis for the gyroscope and for the positioning system was performed. Phase II will concentrate on manufacturing and testing a prototype gyroscope and a miniature positioning system in the field to bring them to the point of commercialization.

Anticipated Results / Potential Commercial Applications as described by the awardee: A low-cost, self-contained positioning and navigation system will find applications where current technology is prohibitively expensive. This is the case for many commercial and military systems such as, for the commercial sector: robotics, vehicles, and instrument stabilization; for the biomedical sector: remote patient activity monitoring; for the automotive sector: smart suspensions and safety-bar actuation; for the military sector: navigation, crash detection, and instrument control; and for the avionics sector: measurement and stabilization.

67

A Vibration Immune Fourier Transform -Infrared Spectrometer for Process Monitoring--On-Tech Joint Venture, P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. Peter R. Solomon, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG05-92ER81339
Amount: $499,462

Fourier Transform Infrared (FT-IR) spectroscopy has been identified as an important new tool to obtain data on species composition, concentrations, and temperature in process monitoring. If FT-IR spectroscopy is to realize this potential, improvement must be made in mechanical stability, thermal stability, ruggedness, size, weight, cost, and field serviceability of the instrument. The goal of this project is to develop a vibration immune, rugged, permanently aligned, thermally stable, low cost Fourier Transform mid-IR absorption spectrometer for industrial process and environmental monitoring. The innovation in this project is an advanced and novel dynamically-balanced "isolation interferometer" with corner cube optics, in which the mirror motion is decoupled from external vibrations. The major achievement in Phase I was the development of an isolation interferometer prototype which demonstrated the ability to reduce, by more than a factor of 60, the effect of external vibrations. This interferometer also demonstrated excellent phase uniformity and expectations of long life, based on accelerated lifetime tests. Phase II will design, construct, and test a complete FT-IR absorption spectrometer incorporating the corner cube isolation interferometer and other advanced components for applications in industrial process and environmental monitoring. Several field tests will also be performed to demonstrate the prototype's performance and to develop data acquisition and process control strategies. Field tests will be performed in at least three applications selected from the pulp and paper, utility power, incineration, chemical, petroleum, and glass industries.

Anticipated Results / Potential Commercial Applications as described by the awardee: A vibration immune, permanently aligned, small, light weight, low cost FT-IR spectrometer will allow application of the technology in thousands of installations with a total market of over $1 billion/year. Applications include: combustion diagnostics, process monitoring, continuous emission monitoring of smoke stacks, ambient air monitoring, auto emission testing, and medical diagnostics. These instruments can provide a significant positive impact on industrial competitiveness by improving efficiency and product quality with lower pollution levels and fewer accidents.

68

Development of a Dielectric Spectroscopy Probe for Charge and Size Analysis of Industrial Colloids--Pen Kem, Inc., 341 Adams Street, Bedford Hills, NY 10507; (914) 241-4777
Mr. Philip J. Goetz, Principal Investigator
Mr. Philip J. Goetz, Business Official
DOE Grant No. DE-FG02-92ER81410
Amount: $499,400

The focus of this project is on the design of a small and robust remote sensor probe to characterize the charge and size of colloidal dispersions (suspensions and emulsions). Such dispersions might have high particle concentration with submicron sized particles and would therefore be unsuitable for optical methods. Many dispersions of interest also have particles with low density contrast, which make them unsuitable for ultrasonic analysis. The planned approach combines rapid measurements of dielectric spectra of the colloid with a deconvolution of the measured spectra to obtain size distribution and charge. The innovation comes from combining expertise in the design of signal processing for colloid instruments (involving electrophoresis and vibration potential) to obtain zeta potentials, with expertise in deconvolution of ultrasound and Fourier transform-infrared (FT-IR) spectra to obtain particle size distributions. In Phase I, a microsensor was designed and fabricated, and research was carried out leading to a proof of concept, based on testing with several colloid systems. During Phase II, the probe design will be improved and extended, and new deconvolution algorithms will be developed using the real and imaginary parts of the measured spectra. Some advances in current theoretical understanding of underlying polarization phenomena are needed to address many dispersions of practical interest, for example, accounting for the effects of high particle concentrations. These will be addressed in Phase II. Tests will be performed using both model and industrial colloids to evaluate the performance of the new micro sensor probes, new theoretical relationships, and new deconvolution algorithms.

Anticipated Results / Potential Commercial Applications as described by the awardee: Potential uses of the planned remote sensor probe for dielectric spectroscopy include charge and size characterization of many colloidal dispersions encountered in energy production and/or conservation, involving petroleum, coal, and food, as well as biomedical industries. The sensor is expected to be small and rugged. It can be used like a pH probe or it can be surface-mounted in on-line applications. Examples of applications with recognized energy savings potential include processing of industrial emulsions, heavy crudes, tar sands, food products, and several organic or inorganic pigments.

69

Novel Ultrasonic Thermometers with Non-Metal Sensing Elements for Hostile Environments--Research and Manufacturing Company, Inc., 4400 South Santa Rita Road, Tucson, AZ 85714; (602) 889-7900
Mr. David W. Varela, Principal Investigator
Mr. David L. Swartz, Business Official
DOE Grant No. DE-FG03-92ER81273
Amount: $489,323

The objective of this project is to develop and test ultrasonic thermometer systems with non-metal sensing elements for temperature measurement and control in highly corrosive manufacturing environments. In Phase I, the feasibility of using alumina, sapphire, stabilized zirconia, and graphite for ultrasonic thermometry was demonstrated. Ultrasonic sensors were designed, fabricated, tested, and calibrated to temperatures exceeding 1500°C using each of these materials. Silicon carbide and alumina reinforced with silicon carbide whiskers were tested but deemed unacceptable, due to low sensitivity in the fist case and drift in the second. The feasibility of using alumina sensors in a highly corrosive manufacturing environment was demonstrated at a titanium dioxide production plant. In Phase II, real time, minimally intrusive ultrasonic sensors will be developed for installation, evaluation, and qualification in production plants where the process is sufficiently corrosive to preclude the successful use of conventional instruments. A meaningful number of sensors will be built and tested in actual industrial processes to gather direct information on performance, lifetime, and suitability. Non-metal sensors have the potential of eliminating sensor degradation from chemical and erosive attack thus improving, and in some situations making possible for the first time, the control in real time of many industrial processes. The commercial application of these novel sensors would lead to increased productivity with decreased energy consumption in such industries as steel, chemicals, and metals.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project is anticipated to lead to the development of non-metal temperature measurement sensors which have the potential of surviving the most corrosive environments. Its immediate commercial application is likely to be in the real time control of temperature in steel making, titanium dioxide production, and casting of aerospace components. This project may also have commercial applications in other industries, including pulp and paper, radio frequency oven control, and the nuclear industry.

70

Improved Control of Pulp and Chip Refining Through Direct Measurement of the Number and Severity of Fiber Impacts--The Lektrox Company, 10301 Bellwood Avenue, New Port Richey, FL 34654; (813) 842-3133
Mr. Irving R. Brenholdt, Principal Investigator
Mr. Robert A. Bareiss, Business Official

DOE Grant No. DE-FG05-92ER81342
Amount: $499,525

The purpose of pulp refining is to produce fibers which have good papermaking qualities. The objectives of Phase I were to construct a sensor incorporating new methods for measuring electrical impulses in the refiner housing, to demonstrate the capability of this sensor to acquire and process the signal in a pilot plant refiner on a single wood species, and to show that the acquired signal correlates with traditional methods for measuring refining results, such as horsepower days per ton, pulp freeness, and the physical properties of hand sheets made from these pulps. These objectives have been met. It is well known in the industry that there are many process variables which influence a given pulp's response to refining action. A major objective of Phase II is to learn how these variables influence the output of the new sensor and to what extent this new measurement, derived from the refining action itself, predicts both drainage and paper properties for a wide range of typical mill conditions. These typical conditions will include other types of pulp, e.g. bleached, hardwood, and recycled. The effects of pH, conductivity, and zeta potential will also be determined. These results will lead to the development of a control strategy which will be demonstrated in a mill site. Other important objectives of Phase II will be to determine the capability of the sensor to measure and control chip refining, and to evaluate and optimize refiner plate design. Also, some fundamental studies of the phenomenon will be imitated at a research institute.

Anticipated Results / Potential Commercial Applications as described by the awardee: The use of this sensor for pulp refining will permit greatly improved control of the process, resulting in energy conservation, quality improvement, and productivity increase. Aggregate energy savings may be as high as 6.5 X 10^{12} BTU/year for pulp refining and 4 X 10^{12} BTU/year for chip refining. Additional savings in papermaking as a result of a more uniform input to the paper-making machines could be more than $500,000 per year per machine. Greater use of recycle pulp will become possible to aid the industry in meeting one of its environmental goals.

APPENDIX A

Alphabetical Listing of Awardees

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Advanced Technology Materials, Inc. ***64***
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Affymetrix, Inc. ***8***
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Applied Sciences, Inc. ***13***
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Bend Research, Inc. ***2, 54, 62***
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IGC Advanced Superconductors, Inc. ***32, 33***
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(602) 889-7900

Rochester Photonics Corporation ***44***
Dr. Dean Faklis, Business Official
330 Clay Road
Rochester, NY 14623
(716) 272-3010

Science Research Laboratory, Inc. ***20***
Dr. Jonah Jacob, Business Official
15 Ward Street
Somerville, MA 02143
(617) 547-1122

SE Systems, Inc. ***24***
Mr. Charles W. Roberts, Business Official
26203 Production Avenue, Suite 10
Hayward, CA 94545
(510) 293-3000

Southwest Sciences, Inc. ***53***
Dr. Alan C. Stanton, Business Official
1570 Pacheco Street, Suite E-11
Santa Fe, NM 87501
(505) 984-1322

Spire Corporation ***25, 42***
Mr. Richard S. Gregorio, Business Official
One Patriots Park
Bedford, MA 01730-2396
(617) 275-6000

Supercon, Inc. ***15***
Ms. Elaine Drew, Business Official
830 Boston Turnpike
Shrewsbury, MA 01545
(508) 842-0174

TDA Research, Inc. ***4, 5***
Mr. Michael E. Karpuk, Business Official
12345 West 52th Avenue
Wheat Ridge, CO 80033
(303) 940-2301

TechnoConcepts, Inc. ***27***
Mr. Michael G. Gunby, Business Official
2363 Teller Road, Suite 118
Newbury Park, CA 91320
(805) 376-2336

The Lektrox Company ***70***
Mr. Robert A. Bareiss, Business Official
10301 Bellwood Avenue
New Port Richey, FL 34654
(813) 842-3133

Thermacore, Inc. ***16***
Mr. Richard W. Longsderff, Business Official
780 Eden Road
Lancaster, PA 17601
(717) 569-6551

Tropix, Inc. ***10***
Dr. Irena Bronstein, Business Official
47 Wiggins Avenue
Bedford, MA 01730
(617) 271-0045

TSI Research, Inc. ***22***
Dr. Edward T. Cheng, Business Official
225 Stevens Avenue, Suite 110
Solana Beach, CA 92075
(619) 793-3567

Viscoustech ***61***
Dr. Chandrika Rajagopal, Business Official
2836 Ridge Drive
Allison Park, PA 15101-2511
(412) 486-1087

X-Ray Instrumentation Associates ***6***
Dr. William K. Warburton, Business Official
1300 Mills Street
Menlo Park, CA 94025-3210
(415) 903-9980

X-Ray Optical Systems, Inc. ***7***
Mr. David M. Gibson, Business Official
9 Physics, 1400 Washington Avenue
Albany, NY 12222
(518) 442-5250

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DEPARTMENT OF ENERGY

SBIR

1994

PHASE I AND

PHASE II

AWARDS

SELECTION STATEMENT FOR PHASE I AWARDEES UNDER THE SECOND SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM SOLICITATION FOR FISCAL YEAR 1993 (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0582)

U. S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585
NOVEMBER 4, 1993

SELECTION OF GRANT APPLICATIONS FOR NEGOTIATION OF SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM PROJECTS UNDER THE SECOND FISCAL YEAR (FY) 1993 PROGRAM SOLICITATION (ANNOUNCEMENT DOE/ER-0582)

As a former chairman of the SBIR Application Score Verification Panel appointed to evaluate Phase I applications for the SBIR program, I am familiar with the Panel's evaluation procedures and its methodology. I have received reports from the Technical Topic Managers (TTMs) who were responsible for the review of the eight technical topic areas listed in the solicitation. I believe that the Panel and the TTMs have proceeded in accordance with applicable laws and regulations, that the evaluation has been thorough and equitable, and that the information presented forms a sound basis for selection. Consequently, I have selected 33 applications received under this solicitation for negotiation for award of Phase I FY 1994 SBIR grants. This statement describes the procurement and sets forth the basis for my selection decision.

Procurement Description

The Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564), requires that each Federal agency with an extramural research or research and development budget exceeding $100 million establish an SBIR program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies over the 18 years of the program are as follows:

Fiscal Year	SBIR Set Aside (%)
1983	0.2
1984	0.6
1985	1.0
1986-1992	1.25
1993-1994	1.5
1995-1996	2.0
1997-2000	2.5

Public Law 102-564 also required, for the first time, the participation in the DOE SBIR program of the Department's programs in Environmental Restoration and Waste Management, and Arms Control and Nonproliferation. The second program solicitation for FY 1993 was issued because of this law and contains eight technical topics from these program areas.

Public Laws 97-219 and 102-564 also prescribe that the SBIR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the SBIR program. This phase will have a period of performance which is typically six months in duration. Awards will be up to $75,000 for FY 1994 Phase I projects. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $600,000 for FY 1994 or 1995 Phase II projects. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-SBIR funded Federal contracts for products or services intended for use by the U.S. Government.

In response to the first eleven program solicitations for FYs 1983-1993, DOE received a total of 13,943 Phase I proposals. (These numbers do not include the proposals received in response to the second program solicitation for FY 1993.) Of these proposals, 1,521 resulted in Phase I contracts or grants, and of these 636 were subsequently selected for Phase II awards. The results of the 1994 Phase I grant applications discussed here, from the second program solicitation for FY 1993, will be added to the above figures which demonstrate the high level of volume and interest in the SBIR program.

Applications Received

Outreach efforts for the DOE SBIR program were considerable. DOE mailed out approximately 30,000 FY 1993 second program solicitations to people on the SBIR mailing list and to other individuals requesting copies. In addition, the SBIR solicitation was advertised in the *Commerce Business Daily* on March 22, 1993. It also received coverage in trade journals and newsletters and in various Small Business Administration information releases and conferences.

A total of 509 applications was received in response to the solicitation. The solicitation listed eight technical topic areas to which applicants could respond. The list of technical topic areas and the number of applications received in each area are as follows:

1.	Sensors for Monitoring Environmental Remediation Activities	121
2.	In-Situ Treatment of Heavy Metal Contaminated Soils and Groundwater .	70
3.	Waste Stream Diagnostics and Controls	51
4.	On-Site Treatment of Surface Water and Groundwater	78
5.	In-Situ Bioremediation of Contaminated Sites	37
6.	Arms Control and Nonproliferation Verification and Detection Technology	36
7.	International Atomic Energy Agency Special Safeguards Inspections . .	43
8.	Technologies for Domestic Nonproliferation and Safeguards	67

Six applications received could not be assigned to a specific topic or subtopic.

Of the 509 applications received, 28 were eliminated for administrative reasons; DOE staff determined that these applications failed to meet one or more material requirements of the solicitation.

The remaining 481 were judged on a competitive basis in a two-step process. The first step of that process was a screening by the TTMs and DOE staff

The remaining 481 were judged on a competitive basis in a two-step process. The first step of that process was a screening by the TTMs and DOE staff knowledgeable in the topic area to determine the relevance of each application to a chosen topic by the extent to which it responded to a specific topic area. Then it was determined whether each application was for research or research and development, whether it provided sufficient information for a full evaluation, whether it was duplicative of other ongoing or previous efforts, and finally, whether it was of sufficiently high quality for award. One hundred eighty-nine applications were eliminated after the first step technical review. The 292 applications found to be relevant were evaluated in the second step according to criteria listed in the solicitation and set out below.

Selection Criteria and Rationale

Phase I awards were made on scientific and technical merit based upon the criteria listed below. Approximately equal consideration was given to each of the following criteria:

(1) The scientific/technical quality of the research in the Phase I grant application.

(2) The degree of innovation demonstrated by the grant application.

(3) The qualifications of the Principal Investigator, other key staff, and consultants, if any, and the level of adequacy of available or obtainable instrumentation and facilities.

(4) The anticipated benefits, technical and/or economic, of the proposed research (Phase I and Phase II), if successful, with special emphasis on the likelihood that the project will attract further funding for product or process development after the SBIR support expires.

(5) The soundness and level of adequacy of the Phase I proposed work plan to show progress toward proving the feasibility of the concept.

For each of the eight technical topic areas listed in the solicitation, there was a TTM who, along with reviewers both internal to DOE and external - selected from among DOE Laboratory personnel, university researchers, and private industry personnel - evaluated and scored applications against the assigned criteria. An Application Score Verification Panel (ASVP) consisting of technical staff from both within and without DOE was established to ensure relative uniformity of scoring across the eight topic areas and to ensure that scores were based on meaningful technical reviews. The ASVP was also chartered to ensure that there was consistency of scoring within topics.

I have examined the evaluation documentation presented by the TTMs. I have also carefully reviewed the recommendations of the ASVP and have agreed that the evaluations of the TTMs and the recommendations of the ASVP provided valid bases upon which to make a selection. Therefore, based on those recommendations, and in consideration of applications whose funding would contribute to a programmatically-balanced set of SBIR-supported projects, I have selected 33 applications for negotiations. Included in these are all applications which received either the highest possible technical rating or were within two points of such a rating. It is my view that these applications represent outstanding technical quality and are worthy of selection for this program.

Selected Applications

Appendix A is a listing of the applications selected for negotiations leading to award. The SBIR program is an ongoing one, and continued participation in later solicitations is strongly encouraged.

Samuel J. Barish

Samuel J. Barish
SBIR Program Manager

Date: 11/4/93

Attachment:
List of Grant Applications
  Recommended for Awards

APPENDIX A
DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1994 AWARDS
(SECOND FY 1993 SOLICITATION)

TOPIC: SENSORS FOR MONITORING ENVIRONMENTAL REMEDIATION ACTIVITIES

ALEM Associates 303A Commonwealth Avenue Boston, MA 02115	Activated Optical Ceramics: A New Class of Materials for Environmental Monitoring
ANDCARE, Inc. 2810 Meridian Parkway, Suite 152 Durham, NC 27713	Innovative Electrochemical Sensors for In-Situ Real-Time Monitoring of Lead in Aqueous Media
Berkeley MicroInstruments, Inc. 2375 Cedar Street Berkeley, CA 94708	A Micromachined Piezoelectric Sensor System for Monitoring Environmental Remediation
Covalent Associates, Inc. 10 State Street Woburn, MA 01801	Fluoroionphores for Use in a Fiber Optic Sensor for Mercuric Ions
ICET, Inc. 916 Pleasant Street, Unit 12 Norwood, MA 02062	Potentiometric Sensors for Lead and Mercury
Dr. John Kevin Markey 1298 #1L Hartford Turnpike North Haven, CT 06473	A Compressed Xenon Gamma Sensor for Environmental Measurements
Microsensor Systems, Inc. 62 Corporate Court Bowling Green, KY 42103	A High Frequency Surface Acoustic Wave Device as a Novel Detector for Portable Gas Chromatographs for Field Screening of Hazardous Vapors
Physical Sciences, Inc. 20 New England Business Center Andover, MA 01810-1077	A Nitro and Explosives Monitor for Cone Penetrometer Waste Site Evaluation
Research International, Inc. 18706 142nd Avenue, NE Woodinville, WA 98072	Fiber Optic Sensors for Heavy Metal Cations

TOPIC: IN-SITU TREATMENT OF HEAVY METAL CONTAMINATED SOILS AND GROUNDWATER

Engineering Resources, Inc. P.O. Box 3682 Fayetteville, AR 72702	In-Situ Microbial Metal Immobilization
Environmental Risk Limited 120 Mountain Avenue Bloomfield, CT 06002	Enhanced Mobilization of Heavy Metals Using Sequential Extraction

TOPIC: WASTE STREAM DIAGNOSTICS AND CONTROLS

Laser Diagnostics P.O. Box 4627 Los Alamos, NM 87544	Real Time Monitoring of Heavy Metals Using Laser-Induced Breakdown Spectroscopy
Physical Optics Corporation 2545 West 237th Street, Suite B Torrance, CA 90505	Multimode Sensor Network Media

TOPIC: ON-SITE TREATMENT OF SURFACE WATER AND GROUNDWATER

Bend Research, Inc. 64550 Research Road Bend, OR 97701-8599	Development of a Membrane-Based Hybrid System for Removal of Heavy Metals from Groundwater
Foster-Miller, Inc. 350 Second Avenue Waltham, MA 02154-1196	Innovative Sorbents for the Selective Removal of Heavy Metals from Groundwater

TOPIC: IN-SITU BIOREMEDIATION OF CONTAMINATED SITES

ENVIROGEN, Inc. 4100 Quakerbridge Road Lawrenceville, NJ 08648	Optimization of Prolonged Microbial Activity During In-Situ Degradation of Chlorinated Organics
TPL, Inc. 3768 A/B Hawkins, NE Albuquerque, NM 87109	Heavy Metal Bioremediation Using Mycorrhizal Plants

TOPIC: ARMS CONTROL AND NONPROLIFERATION VERIFICATION AND DETECTION TECHNOLOGY

Atlantic Aerospace Electronics Corporation 470 Totten Pond Road Waltham, MA 02154	Multi-Spectral and Multi-Scale Detection/Discrimination of Man-Made Objects
Mission Research Corporation Post Office Drawer 719 Santa Barbara, CA 93102-0719	Fractal Image Processing
Physical Optics Corporation 2545 West 237th Street, Suite B Torrance, CA 90505	A Highly Versatile Tunable Multi-Spectral Imaging Sensor Based on a Micro Spectrographic Array Filter Concept

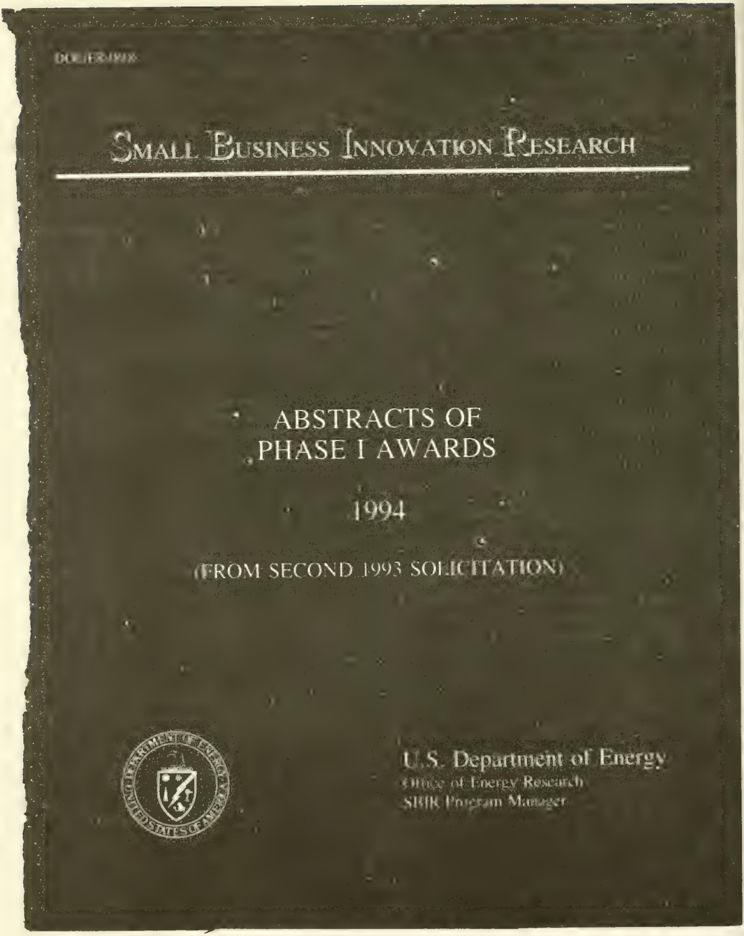
TOPIC: INTERNATIONAL ATOMIC ENERGY AGENCY SPECIAL SAFEGUARDS INSPECTIONS

Atom Sciences, Inc. 114 Ridgeway Center Oak Ridge, TN 37830	Improved Analytical Measurements to Monitor Nuclear Activities
Radiation Monitoring Devices, Inc. 44 Hunt Street Watertown, MA 02172	A Handheld Cadmium Telluride Spectrometer for Nuclear Safeguards Inspections
Stange Associates 5853 Finecrest Drive Rancho Palos Verdes, CA 90274	A Document Imaging, Indexing, and Retrieval System for International Atomic Energy Agency Special Inspections
Tera Research, Inc. 1344 Bordeaux Drive Sunnyvale, CA 94089-1005	A Low-Cost, Remotely Operated, Safeguards Surveillance Satellite Communications Terminal

TOPIC: TECHNOLOGIES FOR DOMESTIC NONPROLIFERATION AND SAFEGUARDS

Advanced Technology Materials, Inc. 7 Commerce Drive Danbury, CT 06810	A Micro Pyrovidicon: An Infrared Imaging Device for Intrusion Detection

Detectronics 2517 Regent Road Livermore, CA 94550	Room-Temperature Gamma-Ray Spectrometers
Halberd 477 West, 5200 North Park City, UT 84060	An Intelligent Intrusion Detection System
MetroLaser 18006 Skypark Circle, Suite #108 Irvine, CA 92714	Development of a Holographic Verification Tag for Secure Inventory
Optiphase, Inc. 7652 Haskell Avenue Van Nuys, CA 91406-2005	An Intelligent Intrusion Detection System Using a Fiber Optic Sensing Network
Radiation Monitoring Devices, Inc. 44 Hunt Street Watertown, MA 02172	A Miniature Charge Sensitive Preamplifier Using Pulsed Drain Feedback
RAND Technologies Corporation 9461-B Silver King Court Fairfax, VA 22031	Development of an Automated Radio Frequency Tagging Method for Tamper Protected Inventory Control of Special Nuclear Material Containers
Synetics Corporation 540 Edgewater Drive Wakefield, MA 01880	RENAM: A Radio Frequency Identification Asset Management System for Nuclear Materials
Xsirius, Inc. 4640 Admiralty Way, Suite 214 Marina del Ray, CA 90292	An Ultra-Compact Cesium Iodine/Mercuric Iodide Gamma-Ray Scintillation Spectrometer



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SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE I AWARDS

1994

(FROM SECOND 1993 SOLICITATION)

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager

DOE/ER-0606

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE I AWARDS

1994

(FROM SECOND 1993 SOLICITATION)

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager
Washington, D.C. 20585

PREFACE

The Federal SBIR Program

This program, now completing its eleventh year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Eleven Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over $100 million. The agencies were required to set aside 1.5% of those budgets in Fiscal Year (FY) 1993 to fund SBIR projects. (This amounted to about $50 million in FY 1993 for the Department of Energy.) Each agency solicits proposals from small science- and technology-based US firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to $75,000 in FYs 1993 and 1994. Phase II is the principal research or R&D effort, and the awards were as high as $500,000 in FY 1993 for work to be performed in a period of up to two years. Phase III is the commercial application of the research or R&D effort by the small businesses using non-Federal funding or, alternatively, it may involve follow-on non-SBIR Federal contracts for products or services desired by the Government. The program continues to strengthen the role that small, innovative firms play in meeting the Nation's research and development needs and in commercialization of ideas developed through federally funded R&D.

Phase I Awards for FY 1994

Contained in this booklet are abstracts of the Phase I awards made in FY 1994 as a result of the second DOE SBIR program solicitation for FY 1993. This solicitation was issued in accordance with PL 102-564 which requires, for the first time, the participation in SBIR of the Department's programs in Environmental Restoration and Waste Management, and Arms Control and Nonproliferation. The DOE resumed its standard practice of issuing one SBIR solicitation per year in FY 1994.

The 32 Phase I projects described here were selected in a highly competitive process from a total of 509 grant applications received in response to the FY 1993 DOE second SBIR solicitation. The selections for awards were made on scientific and technical merit, as judged against the specific criteria listed in the solicitation. Conclusions were reached on the basis of detailed reports returned by reviewers drawn from DOE laboratories, universities, private industry, and government. (Any discrepancies noted in prior DOE releases naming the firms selected for awards are due either to the firm changing its name after the award selection or to the firm not proceeding to a signed grant.) It is expected that between one-third and one-half of the Phase I projects will be continued into Phase II.

The work described in the abstracts is novel, high-risk research, but the benefits will also be potentially high if the objectives are met. Brief comments on the potential applications, as described by the awardee, are given after each abstract. Individuals and organizations, including venture capital and larger industrial firms, with an interest in the research described in any of the abstracts are encouraged to contact the appropriate small business directly.

The DOE SBIR Program

DOE's FY 1993 second solicitation contained 8 technical topics in the areas of environmental restoration and waste management, arms control and nonproliferation, and security affairs. There is keen competition because awards are made solely on the basis of scientific and technical merit, regardless of the technical topic.

As a measure of the program's success, ten DOE SBIR projects have received R&D-100 Awards from Research and Development Magazine, which selects the 100 most significant technical products each year. In addition, five DOE awardees were chosen among the 500 fastest-growing American private companies, in the December 1991 issue of Inc. Magazine, based on their growth in sales. Also, from the first five cycles of awards (Phase II projects completed between 1986 and 1990), DOE SBIR winners have already received over $230 million in Phase III funding, which is more than 50% larger than the SBIR support they were given. This number is expected to grow significantly in the next few years.

The DOE SBIR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. In the first year of Phase II awards (1984), a system was devised and implemented that allowed Phase I awardees who felt they were ready to submit their Phase II proposals before their Phase I grants ended, to do so. For each of the ten years in which Phase II awards have been made, such grantees who were chosen for Phase II funding were able to begin their projects without an interruption in funding. Since 1984, about 40 per cent of the Phase II awardees have had continuous funding between Phases I and II.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, DOE has instituted a special training project, supported by non-SBIR funds. For the past four years, successful Phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participation in the 1991 project, the SBIR companies have already received more than $7.8 million for commercialization of their SBIR research with a projected royalty stream from option agreements of an additional $24 million over the next five years. About 43% of the firms that completed the project have received further funding for their work.

The SBIR program enables DOE to obtain effective, innovative solutions to important problems through the private sector, which has a commercial incentive to pursue the resulting technology and bring it to the marketplace. The growing number of awardees, many of them started in business in response to SBIR solicitations, is becoming a significant resource for the solution of high risk, high technology problems for the Department.

Samuel J. Barish
SBIR Program Manager
US Department of Energy
Washington, DC 20585

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SENSORS FOR MONITORING ENVIRONMENTAL REMEDIATION ACTIVITIES

1

Activated Optical Ceramics: A New Class of Materials for Environmental Monitoring--ALEM Associates, 303A Commonwealth Avenue, Boston, MA 02115; (617) 236-1025
Mr. Charles Brecher, Principal Investigator
Dr. Alexander Lempicki, Business Official
DOE Grant No. DE-FG02-94ER81656
Amount: $74,970

There is an urgent need for sensors capable of in-situ monitoring of radioactive contamination in soils, groundwater, or other environmental media. Since gamma-ray spectral analyses offer the most promising approach for such monitoring, innovative scintillator materials that are faster, brighter, and more sensitive would go a long way towards meeting this need. Most presently known scintillator materials, however, find their application limited by deficiencies in one or more of the desired characteristics: brightness, stopping power, speed, chemical stability, and low cost. A new class of materials is suggested as candidates for high-performance scintillators for radon detection. These materials, denoted activated optical ceramics, overcome most of the limitations inherent in those currently used for scintillator applications. They have high density; they exhibit high-intensity luminescence under ionizing excitation; their emission decay times are extremely short (in the nanosecond range); they are insoluble in water and chemically inert in any ambient environment; and they are relatively easy to fabricate. This Phase I project will explore the potential of these materials for such scintillator applications. Initial spectroscopic and kinetic measurements on uncompacted powders will identify a reasonable composition, and a ceramics processing effort will demonstrate fabricability and lay the groundwork for full-scale exploitation in Phase II of the program.

Anticipated Results / Potential Commercial Applications as described by the awardee: The project would employ the unique advantages of ceramic processing to generate a line of superior scintillators for monitoring of radioactive contamination of the environment, and promote the broader use of radiographic technology in industrial and analytical applications.

2

Innovative Electrochemical Sensors for In-Situ Real-Time Monitoring of Lead in Aqueous Media--ANDCARE, Inc., 2810 Meridian Parkway, Suite 152, Durham, NC 27713; (919) 544-8220
Dr. John P. O'Daly, Principal Investigator
Mrs. Carolyn J. Henkens, Business Official
DOE Grant No. DE-FG05-94ER81657
Amount: $75,000

There is need for innovative electrochemical sensors for monitoring chemical composition in situ, in real time, without removing samples of material for subsequent analysis. This is because the chemical components of interest in many measurements may be unstable or because immediate information on changes in composition may be required. This advanced sensor technology will have applications in post-closure monitoring of environmentally remediated sites. This Phase I project will develop innovative amperometric electrochemical sensors containing colloidal gold particles that facilitate continuous, in-situ, real-time monitoring of lead in ground water and other aqueous media. The amperometric method for lead detection with the proposed electrochemical sensor will consist of three distinct steps. First, a negative potential is applied to reduce the Pb^{++} to elemental lead on the colloidal gold surface. Second, a positive potential is applied to strip off the deposited lead. A third potential is applied to clean the electrode surface for the next cycle of Pb^{++} detection. The anticipated result is a sequenced waveform of pulses and ramps that will produce a novel stripping electrochemical sensor able to continuously monitor for lead in in-situ conditions. If successful, this technology will enable simple fabrication of advanced sensors for analytical chemical measurements useful in National environmental screening and monitoring programs. The technology will lower production costs of electrochemical sensor production and increase sensor performance resulting in a reduction of environmental remediation costs.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project should lead to colloidal gold coated amperometric electrochemical sensors for real-time, continuous monitoring of lead in groundwater and other aqueous media useful for National environmental screening and monitoring programs.

3

Fluoroionophores for Use in a Fiber Optic Sensor for Mercuric Ions--Covalent Associates, Inc., 10 State Street, Woburn, MA 01801; (617) 938-1140
Dr. Christopher Blackburn, Principal Investigator
Dr. Victor R. Koch, Business Official
DOE Grant No. DE-FG05-94ER81662
Amount: $75,000

A series of new fluoroionophores designed to bind and respond optically to the mercury (II) ion in aqueous solutions will be synthesized and tested. The response will involve a shift in absorption wavelength and/or fluorescence quenching. The fluoroionophores are to be used in a fiber optic sensor for Hg^{2+} and are based on coumarin as fluorophore and contain a macrocyclic structure as the metal binding site. In Phase I, the influence of Hg^{2+} on the optical properties of the fluoroionophores will be investigated and the selectivity of the response in the presence of other metal ions will be determined. The abilities of the ionophores to extract Hg^{2+} into an organic phase will be assessed, and methods for their immobilization in a polymeric membrane will be studied.

Anticipated Results / Potential Commercial Applications as described by the awardee: The development of a fluoroionophore that responds selectively to the mercury (II) ion will provide the basis of a fiber optic sensor for Hg^{2+} and for total mercury. This device would be marketed to scientists involved in environmental monitoring, e.g., for assessing the efficiency of clean-up operations at waste sites, and for the determination of mercury levels in oceans and in fresh water.

4

Potentiometric Sensors for Lead and Mercury--ICET, Inc., 916 Pleasant Street, Unit 12, Norwood, MA 02062; (617) 769-6064
Dr. Shantha Sarangapani, Principal Investigator
Dr. Srinivasan Sarangapani, Business Official
DOE Grant No. DE-FG02-94ER81669
Amount: $75,000

Potentiometric sensors for lead (II) and mercury (II) are being studied. The sensors, based on highly selective extractive ionophores, are expected to overcome the technical limitations faced by a few other sensors that have been tested. Some preliminary results have been obtained. The Phase I research will thoroughly explore the feasibility of the use of selective ionophores for lead and mercuric ions in a polymeric matrix and examine their detection limits (up to 10 ^{9}M), stability, selectivity, and durability in heavy metal soups with typical DOE contamin-ants, including some complexing anions.

Anticipated Results / Potential Commercial Applications as described by the awardee: The in-situ sensors for lead ions and mercuric ions could find commercial applications in environmental monitoring and even testing of drinking water and agricultural products.

5

A Compressed Xenon Gamma Sensor for Environmental Measurements--Dr. John Kevin Markey, 1298 #1L Hartford Turnpike, North Haven, CT 06473; (203) 230-0894
Dr. John Kevin Markey, Principal Investigator
Dr. John Kevin Markey, Business Official
DOE Grant No. DE-FG05-94ER81670
Amount: $74,955

In response to the need for compact, rugged gamma-ray sensors with high counting efficiency and good photopeak resolution, this project will develop sensor technology for both aboveground surface contamination mapping as well as for underground (well logging) applications. This work derives from the recent development of high resolution gamma detectors in the Yale University physics department based on xenon near its thermodynamical critical point. The Phase I objective is to design, construct, test and evaluate for gamma ray performance (photopeak resolution, absolute efficiency, count rate) a detector operating at room temperature at xenon densities from 0.5 to 1.4 grams/ml. In addition, the potential improvements in performance, particularly dead-time (count rate), with the addition of 1 to 5% helium will be measured.

Anticipated Results / Potential Commercial Applications as described by the awardee: The sensor technology of a compact, high resolution, room temperature, portable gamma-ray detector will find application in environmental measurements, industrial process monitoring, and nuclear medicine.

6

A High Frequency Surface Acoustic Wave Device as a Novel Detector for Portable Gas Chromatographs for Field Screening of Hazardous Vapors--Microsensor Systems, Inc., 62 Corporate Court, Bowling Green, KY 42103; (502) 745-0099
Dr. Hank Wohltjen, Principal Investigator
Dr. Hank Wohltjen, Business Official
DOE Grant No. DE-FG05-94ER81673
Amount: $74,041

The very small size and high performance inherently possible with miniature gas chromatographs (GC) based on lithographically fabricated micro columns has never been realized due primarily to limitations in detector technology. This study will explore the novel concept of developing a very small surface acoustic wave (SAW) resonator device as a detector for such a micro column. SAW detectors offer significant advantages over conventional thermal conductivity or ionization detectors. They can use air (or other ambient gas) as the carrier gas, they require no heating or ionization process, and they can be used as universal detectors or as specific detectors. Their performance can be optimized for specific classes of chemicals by covering the SAW surfaces with appropriate chemically specific coatings. The SAW device can also be cooled to liquid nitrogen temperatures and used as a universal or quantitative detector with very fast response. The projected SAW GC detector will have an oscillating frequency of 400 MHz, will be sensitive to organic vapors in the ppb range, and have a dead volume less than one micro liter. In Phase I it will be determined whether the 400 MHz SAW resonator device can achieve the predicted performance goals and whether it has the expected advantages over the GC detectors now in use.

Anticipated Results / Potential Commercial Applications as described by the awardee: SAW GC detectors, using air as the carrier gas and having very small dead volumes, will greatly extend the capabilities of miniature GCs, especially as portable monitors for hazardous organic vapors. It is expected that miniature GCs with SAW detectors will find ready markets in a variety of industrial hygiene and environmental monitoring applications.

7

A Nitro and Explosives Monitor for Cone Penetrometer Waste Site Evaluation--Physical Sciences, Inc., 20 New England Business Center, Andover, MA 01810-1077; (508) 689-0003
Dr. William J. Marinelli, Principal Investigator
Mr. George E. Caledonia, Business Official
DOE Grant No. DE-FG02-94ER81678
Amount: $75,000

The characterization and monitoring of DOE hazardous waste sites is an expensive and time consuming process. The development of the cone penetrometer (CP) and supporting instrumentation under the DOD Site Characterization and Analysis Penetrometer System (SCAPS) program has reduced the costs associated with the boring of the test wells by approximately an order of magnitude and has been adopted by DOE. A significant barrier to the widespread use of the SCAPS system is the development of diagnostic techniques for the 1-in. interior dimension of the penetrometer shaft. The detection of trace explosives such as TNT, RDX, and HMX in soils is difficult since they have low vapor pressures, poor ultraviolet-visible absorption characteristics, and decompose in sunlight and with moderate heating. This project will develop an innovative, continuous sensor for the CP which would facilitate the detection of explosives and nitro-compounds in arid and saturated soils. The Phase I effort will experimentally investigate the feasibility of the method in a laboratory mock-up of the CP in order to place firm detection limits on the technique. In Phase II these results would be used to design, build, and field test a detection system in a CP.

Anticipated Results / Potential Commercial Applications as described by the awardee: The Phase I effort should demonstrate the feasibility and sensitivity of the proposed approach for the detection of trace explosives in soils. Potential applications exist at hazardous DOE waste sites and for the detection of trace explosives in soils.

8

Fiber Optic Sensors for Heavy Metal Cations--
Research International, Inc., 18706 142nd Avenue, NE,
Woodinville, WA 98072; (206) 486-7831
Dr. David A. McCrae, Principal Investigator
Ms. Joyce M. Brien, Business Official
DOE Grant No. DE-FG03-94ER81682
Amount: $74,941

New technologies designed specifically for the economical monitoring of chemical contaminants as mandated by Federal and State regulations are needed. In particular, the Department of Energy requires sensors for site characterization and monitoring, and for remediation and waste process monitoring. Optical chemical sensors could provide a method to meet this need. This project addresses the specific need for sensors capable of monitoring heavy metal ion contaminants such as lead, copper, and cadmium. The approach relies on the spectral changes that can occur when a metal cation is complexed by a macrocycle containing an integral chromophore. In distinction from other optical methods, this approach directly operates in an aqueous environment and does not require any type of phase separation. An initial experiment has demonstrated the ability to distinguish 10 mM lead in the presence of 300 mM sodium, with a limit of detection (LOD) of 200 ppm. This project will attempt to reduce the LOD to below 1 ppm in Phase I, and establish the backgrounds necessary to provide an LOD of less than 1 ppb in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: The successful conclusion of this research will result in optical sensors for the continuous, inexpensive monitoring of heavy metal ions such as lead and copper. Such monitoring systems are necessary to meet new regulations concerning heavy metal contamination. For example, the EPA has mandated that water supply systems monitor the lead concentration of drinking water in households to determine treatment actions.

IN-SITU TREATMENT OF HEAVY METAL CONTAMINATED SOILS AND GROUNDWATER

9

In-Situ Microbial Metal Immobilization--
Engineering Resources, Inc., P.O. Box 3682,
Fayetteville, AR 72702; (501) 575-4108
Dr. E. C. Clausen, Principal Investigator
Mr. S. S. Adams, Business Official
DOE Grant No. DE-FG05-94ER81664
Amount: $75,000

Many subsurface vadose sites around the nation are severely contaminated with heavy metals that are migrating into the groundwater. Suitable treatment methods to remove these metals are not available. Current methods of immobilization, including adsorption, ion exchange, or precipitation, are not effective for some metals and allow slow release and continued migration of other metals. This project will investigate a unique biological method to stabilize metals by forming a limestone monolith from microbially enhanced precipitates in situ. This technique, employed successfully for sealing channels in petroleum reservoirs, would immobilize all metals present, and the process could be readily reversed for future metals removal, as suitable technologies become developed. This process requires only the dispersion of bacteria and substrates in solution in the soil and could be readily applied to many soil types. The technique could also prove very useful for rapid stabilization of zones around a toxic spill. Phase I of this project will identify the best microorganisms and substrate concentrations to carry out the reactions to biologically produce limestone in situ. Experiments will be conducted in reactors simulating in-situ conditions to measure the permeability and metal migration within the biological limestone. The cost of this method of solubilization will be projected. Phase II will optimize the process and examine the parameters on a larger scale. Studies will be performed to determine methods to effectively and quickly disperse nutrients and bacteria within contaminated zones for various soil heterogeneities. A field demonstration at a selected site will also be conducted in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful completion of Phase I and Phase II of this project will provide an inexpensive and effective method for stabilizing existing contaminated regions, as well as future spill areas. The method should apply to all metal or organic contaminants and to most vadose zone soils. The U.S. has several thousand waste sites where this technology can be applied once successfully demonstrated.

10

Enhanced Mobilization of Heavy Metals Using Sequential Extraction--Environmental Risk Limited, 120 Mountain Avenue, Bloomfield, CT 06002;
(203) 242-9933
Ms. Elaine M. Hammick, Principal Investigator
Dr. Gordon T. Brookman, Business Official
DOE Grant No. DE-FG05-94ER81666
Amount: $74,783

Heavy metals such as chromium, cadmium, lead, and nickel are often found to have contaminated soils and groundwater at metal finishing shops, landfills, and manufacturing facilities. Currently, the most commonly used remedial technique is to remove the soil from the site for off-site fixation. Because of the high cost of transportation of the soil and diminishing capacity of hazardous waste landfills, more emphasis is being given to methods that can be applied to soils for in-situ treatment. Some studies have been performed to determine the best reagents to apply to the soils to mobilize and remove heavy metals. Unfortunately, many of these studies focused on the use of chelating agents. While chelating agents are effective in removing metals from soils, the leachate generated cannot be treated by most commercially available wastewater treatment systems which are found at many metal finishing operations and manufacturers. A method has been developed, called sequential extraction, which removes the metals sequentially from the extractable, organically occluded, and iron/manganese occluded portions of the soil. This method does not use chelating agents, and has been used successfully in laboratory scale studies. The purpose of this Phase I research is to apply sequential extraction to column scale tests. The research will also investigate manipulating the concentration of the chemicals used in sequential extraction so that lower concentrations of chemical reagents can be applied in situ, which would lower impact of the reagent on the environment and workers should a spill of the material occur. This will also require column testing of contaminated soil samples.

Anticipated Results / Potential Commercial Applications as described by the awardee: The DOE, the Federal Government, and the private sector are all affected by the problems associated with the contamination of soils and groundwater by heavy metals. Because of the high costs and risks associated with off-site treatment, an in-situ method for treatment of soils contaminated with heavy metals needs to be developed. This research is aimed at providing a method for treating soils contaminated with heavy metals in situ. This method can be applied at hazardous waste sites, Resource Conservation and Recovery Act sites, and Superfund sites in a safe and economical manner.

WASTE STREAM DIAGNOSTICS AND CONTROLS

11

Real-Time Monitoring of Heavy Metals Using Laser-Induced Breakdown Spectroscopy--Laser Diagnostics, P.O. Box 4627, Los Alamos, NM 87544;
(505) 672-3632
Dr. Gary W. Loge, Principal Investigator
Dr. Gary W. Loge, Business Official
DOE Grant No. DE-FG02-94ER81671
Amount: $75,000

The Department of Energy (DOE) hopes to use thermal treatment to reduce the volume of its waste materials, minimizing waste handling and storage problems. New Environmental Protection Agency regulations on the amount or rate of heavy metal release into the atmosphere from thermal treatment and process off-gases are currently planned. A method to monitor thermal treatment off-gases for these regulated heavy metals is essential to demonstrate compliance. Laser-Induced Breakdown Spectroscopy (LIBS), which uses the emission from a laser-induced spark for elemental analysis, appears to offer sufficient sensitivity to be useful for detection of heavy metals at or below the regulated levels. This technique has already proven useful for the detection of airborne beryllium metal in a portable system. Application of this technique to the analysis of thermal treatment off-gases has several potential problems. This Phase I project will investigate the effects of the surrounding gas temperature on the calibration when the metal is in the form of hot vapor or particles of inorganic compounds. Calibrations of cadmium under these different conditions are planned to verify the calibration reliability.

Anticipated Results / Potential Commercial Applications as described by the awardee: Application of the techniques of laser-induced breakdown spectroscopy to the analysis of heavy metals in off-gases appears to be useful. With new regulations on the release of heavy metals into the atmosphere, many potential customers exist for a device based on this technique.

12

Multimode Sensor Network Media--Physical Optics Corporation, 2545 West 237th Street, Suite B, Torrance, CA 90505; (310) 320-3088
Dr. Vladimir Katsman, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-94ER81676
Amount: $74,983

In order to identify the presence and concentrations of various contaminants, and to support processing decisions, this project will investigate the development of a novel mutimode sensor network media (MSNM) which will provide real-time monitoring capability for a large number of sensors. The MSNM will also provide high performance routing of the resulting data to controllers, which can then send process corrections for controlling toxicity and waste composition. Currently existing waste stream diagnostic systems at chemical processing facilities use multiple sensors to analyze contaminants in the waste stream. Unfortunately, the results may not be timely enough to prevent problems. In order to perform real-time monitoring and process control, these systems must be capable of transmitting multiple signals at very high speeds (>500 Mhz). They must also be compatible with a variety of sensors. The MSNM will use an analog and digital approach to receive data from different sensors (radioactivity, pH, reactive compounds, heavy metals, etc.). This will be achieved through the combination of conventional electronics and proprietary analog/digital optical data links, capable of receiving and sending multiple signals through a single fiber. The Phase I program includes the determination of the MSNM system specifications and the subsequent design and integration of all the required optical and electrical components.

Anticipated Results / Potential Commercial Applications as described by the awardee: The multimode sensor network media will provide in-process diagnostic and control systems for high level waste stream radiation applications, and for industrial process controls. It could also be used for high level radiation diagnostics in various nuclear physics applications.

ON-SITE TREATMENT OF SURFACE WATER AND GROUNDWATER

13

Development of a Membrane-Based Hybrid System for Removal of Heavy Metals from Groundwater--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. Rod Ray, Principal Investigator
Dr. Rod Ray, Business Official
DOE Grant No. DE-FG03-94ER81660
Amount: $75,000

Groundwater at many sites (e.g., abandoned mines, Government research sites) has become contaminated with heavy metals, including Cu, Zn, and Pb. These metals must be removed so that the water can be used and further contamination prevented. Processes exist that can effectively remove the metal ions from groundwater, but they are not selective enough to recover the metals at a purity required for subsequent refining. An economical hybrid process will be developed promising the recovery of the metals in pure form while at the same time producing a clean-water stream suitable for discharge. The hybrid process combines membrane-mediated solvent extraction (SE) with reverse osmosis (RO). Here, the SE step removes and concentrates the metals, while the effluent from the SE system, which contains low concentrations of extraction chemicals, is treated by a robust, fouling-resistant hollow-fiber RO membrane module to produce a clean permeate stream. The goal of the Phase I program is to demonstrate the feasibility of this "SERO" hybrid system. Key to demonstrating feasibility is the development of chemically stable RO membranes that are capable of operating on the harsh fouling-prone SE effluent. Specifically, a new class of chemically resistant polymers that promises to provide the necessary robustness will be investigated. These modules would then be tested in a small-scale hybrid SERO system. The Phase II effort would complete the development of these fibers, make large-scale modules, and build a breadboard unit. This hybrid system would then be operated on synthetic contaminated groundwater, providing the necessary engineering data required to fully evaluate the economic viability of the process. At the end of the Phase II program a field test of this technology would be performed at a site containing groundwater contaminated with heavy metal ions.

Anticipated Results / Potential Commercial Applications as described by the awardee: The SERO hybrid process would be relevant to virtually all applications requiring the removal of heavy metals from water, including treatment of groundwater, surface waters, and industrial wastewaters. Additionally, the chemically resistant RO modules to be developed could have key applications beyond the proposed hybrid system, including treatment of industrial wastewater streams that cannot be treated by conventional RO technology because of its lack of chemical resistance. As such, there is a large potential market for this technology.

14

Innovative Sorbents for the Selective Removal of Heavy Metals from Groundwater--Foster-Miller, Inc., 350 Second Avenue, Waltham, MA 02154-1196; (617) 890-3200
Dr. Harris Gold, Principal Investigator
Mr. Adi R. Guzdar, Business Official
DOE Grant No. DE-FG02-94ER81667
Amount: $74,985

Groundwater at some DOE facilities is contaminated with heavy metals such as copper, lead, and zinc, in the fairly high concentration range of 1,000 to 10,000 ppm. These metals originate from two sources, namely inactive waste sites and abandoned mines. It is desirable to remove the metals from the contaminated groundwater for subsequent refining with innovative sorbents. The innovative sorbents that are to be developed under the proposed program are phase transition gels that have a strong affinity for heavy metals. Phase transition gels are polymers that undergo large volume changes upon exposure to small changes in various external stimuli, such as temperature or light. During these volume changes, the heavy metals are released from the gels, allowing the gels to be continually reused without replacement. The sorbents are also reversible, can be regenerated with innocuous low cost stimuli, such as heat and light, and do not require the use of chemicals which are expensive and generally produce a concentrated waste that must be disposed of. The sorption process has the potential for dramatically reducing the costs of regeneration by an order of magnitude as compared to commercial metal separation processes. The Phase I work will concentrate on the development of phase transition gels containing chelating agents. The chelating agents to be used will be specific to heavy metals such as lead, zinc, and/or copper. Tests will be carried out to determine (1) the capacity of the gels, (2) the selectivity of the gels to lead, zinc, and copper in the presence of iron, (3) the regeneration of the gels, (4) the degree of removal of the heavy metals from water solutions, and (5) the degree of concentration of the heavy metals after regeneration.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project should result in the selective removal of valuable heavy metals from water and wastewater for recovery and/or process reuse with extremely low energy consumption and without the use of treatment chemicals. Specific applications include the removal of lead, zinc, and/or copper from contaminated groundwater at abandoned mine sites in a form that is amenable for metal reclamation.

IN-SITU BIOREMEDIATION OF CONTAMINATED SITES

15

Optimization of Prolonged Microbial Activity During In-Situ Degradation of Chlorinated Organics--ENVIROGEN, Inc., 4100 Quakerbridge Road, Lawrenceville, NJ 08648; (609) 936-9300
Dr. Robert J. Steffan, Principal Investigator
Mr. William J. Guarini, Business Official
DOE Grant No. DE-FG05-94ER81665
Amount: $75,000

In-situ biological treatment of aquifers contaminated with volatile organic compounds (VOCs) is a viable remediation technique that facilitates the complete destruction of the contaminating compounds. The successful implementation of this technology relies on the use of biocatalysts that can sustain high levels of desired metabolic activity for extended periods of time. One method for maintaining desired metabolic activity is the use of superior degradative microorganisms that possess the enzymes necessary for degrading VOCs and are enriched in bacterial storage polymers such as poly-beta-hydroxybutyrates (PHB). These organisms will carry their own energy reserves into the contaminated aquifer, and thus will not require in-situ feeding. In-situ feeding of high concentrations of nutrients can result in biofouling and competition from indigenous microorganisms. In Phase I methods will be developed for culturing the VOC-degrading microorganisms so that they contain elevated levels of PHB, and methods will be developed by which the desired degradative genes can be induced and remain induced for extended periods of time without the addition of cosubstrates. This in-situ approach will provide an inexpensive, efficient alternative to current treatment technologies, and it will alleviate the biofouling and low degradation efficiency typically experienced in many previous in-situ studies.

Anticipated Results / Potential Commercial Applications as described by the awardee: Completion of this research will lead to development of an in-situ remediation strategy for treatment of chlorinated solvent-contaminated groundwater. The work will be the final step in an integrated approach to in-situ remediation, and provide the information needed to develop a rational and economically feasible approach for cleaning many of the nation's contaminated groundwaters.

16

Heavy Metal Bioremediation Using Mycorrhizal Plants--TPL, Inc., 3768 A/B Hawkins, NE, Albuquerque, NM 87109; (505) 344-6744
Dr. K. Blake Kidd, Principal Investigator
Mrs. Caroline F. Eisenhood, Business Official
DOE Grant No. DE-FG03-94ER81686
Amount: $55,217

The remediation of soil and water contaminated with toxic metals presents a serious challenge to known cleanup methods. Ex-situ remediation of some metal contaminated sites has been demonstrated on a small scale using specially adapted microbes, but removal of the contaminated soil and slow turnover rates downgrade this method. Mycorrhizal plants show great potential, but the capability of these plants to accumulate metals on a scale practical for cleanup has not been demonstrated. A *Glomus* species of mycorrhizae will be introduced into alfalfa and *Sudan* sorghum plants. The plants will be grown in soil that has been contaminated with low or high levels of lead, chromium, and cadmium, and in soil that is uncontaminated. The different root systems for these plants allow investigation into depth of remediation. Also, a small scale plot test will be performed to demonstrate the feasibility of this technique on an actual contaminated site. These crop plants, because of the advantages of wide geographic distribution, fast growth, multiple cuttings, commercially available seed, genetic variability, and known agronomics, could significantly enhance mycorrhizal plant metal accumulation as a site remediation technique. The Phase I study will evaluate the extent of metal removal in comparison with the plant types and contamination levels. Final site evaluation and recommendations for disposal of the plant matter will be considered for extension into Phase II activities.

Anticipated Results / Potential Commercial Applications as described by the awardee: The benefit of this program is in the use of a natural, economical method to remove toxic metals from contaminated soil. Some commercial applications of mycorrhizal plant metal accumulators would be in remediation and reclamation of mine spoils, lead battery dumps, and radionuclide contaminated areas.

ARMS CONTROL AND NONPROLIFERATION VERIFICATION AND DETECTION TECHNOLOGY

17

Multi-Spectral and Multi-Scale Detection/Discrimination of Man-Made Objects--Atlantic Aerospace Electronics Corporation, 470 Totten Pond Road, Waltham, MA 02154; (617) 890-4200
Ms. Tamar Peli, Principal Investigator
Dr. Theodore Bially, Business Official
DOE Grant No. DE-FG02-94ER81658
Amount: $74,955

This project studies an innovative approach to the detection and discrimination of man-made objects in multi-spectral imagery. The major advantages of this process are: (1) significant performance improvements over existing approaches, and (2) less stringent hardware requirements for real-time implementation than current state-of-the-art techniques. The task of identifying arms control and nonproliferation violations from remotely sensed data requires the ability to distinguish image features based on very subtle cues, resulting in labor-intensive, manual processes. The manual interpretation is time consuming and as a result there are not enough analysts to go through the large quantity of data collected. A fractal-based processing system which can respond to subtle differences in image texture is being studied for the detection and discrimination of man-made objects embedded in the natural clutter. The developed techniques will enable a photo interpreter to quickly screen the enormous amount of imagery currently being collected. More specifically, the procedures developed under the Phase I program will automatically direct a human analyst to image regions consisting of man-made structures. In Phase II the initial cueing capabilities will be extended to include object identification and the indication of structural changes. Final decisions on the occurrence of violations will be made by human photo interpreters, but the automated procedures to be developed will increase their productivity.

Anticipated Results / Potential Commercial Applications as described by the awardee: The algorithms developed under the Phase I and II programs will be integrated into a software package and marketed as an application upgrade for analyst workstations. The targeted application base will span a number of diverse application areas, including arms control and proliferation verification, military reconnaissance, and surveillance and intelligence. In addition, the technology developed under this effort has commercial applications including drug interdiction (surveillance), nondestructive evaluation (defect detection) and biomedical image applications.

18

Fractal Image Processing--Mission Research Corporation, 735 State Street, P.O. Drawer 719, Santa Barbara, CA 93102-0719, (805) 963-8761
Mrs. Meg A. Noah, Principal Investigator
Mr. Scot R. Fries, Business Official
DOE Grant No. DE-FG03-94ER81674
Amount: $74,994

There is a requirement to develop systems for the verification of arms control treaties and for the detection of proliferation of weapons of mass destruction. One need in this area is to detect man-made objects in natural backgrounds. It has been recognized that natural objects have fractal geometry and that the irregularity or roughness of the natural objects can be characterized with fractal dimension estimates in imagery. This project will develop, implement, and evaluate innovative techniques for measuring fractal parameters and apply these techniques for the detection of man-made objects in natural backgrounds. Phase I will (1) extend current 2D fractal dimension measurement techniques to multi-temporal, multispectral imagery, (2) invent techniques for real-time characterization of fractal parameters such as correlation length and ramification, and (3) compare current fractal dimension measurement techniques to the fast fractal estimates and the multi-grid approach. Novel applications of fractal image processing will be explored, including (1) the bulk filtering of natural backgrounds, and (2) the detection and identification of man-made objects in natural backgrounds. The analysis will focus on techniques that can be implemented in real time. The final task of the plan, the design of a hardware/software architecture for real-time fractal processing, will provide the basis for Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: This effort will provide a critical review of successful elements of target detection schemes that utilize fractal image processing. It will help to establish the best set of fractal parameters that objectively characterize natural backgrounds. It will demonstrate the utility of fractal parameters for bulk screening in wide area searches, elimination of false detections, and identification of man-made objects. The project will establish the baseline criteria for a real-time fractal-assisted image processing system for recognition of man-made objects in natural backgrounds.

19

A Highly Versatile Tunable Multi-Spectral Imaging Sensor Based on a Micro Spectrographic Array Filter Concept--Physical Optics Corporation, 2545 West 237th Street, Suite B, Torrance, CA 90505; (310) 320-3088
Dr. Tin M. Aye, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-94ER81677
Amount: $74,980

This project will develop a unique nanotechnology for the cost-effective production of a compact, low-voltage, high resolution (< 1 nm), widely tunable (visible to near IR), highly rugged, monolithic, highly versatile, 2D array, multispectral imaging sensor (MSIS) system. This new technology is based on the unique integration of microlens arrays, diffractive micro-optics, holographic volume gratings, and high resolution, fast switching liquid crystal (LC) spatial-light-modulator (SLM) arrays. This approach uses multispectral imaging and the spectrographic principle, but without moving parts. The MSIS can effectively dissect the input image into pixel (or small numbers of pixels) size micro regions and spectrally filter each region using a cascaded array of microimaging spectrometers. A combination of a refractive lenslet array and a diffractive and high-efficiency (>95%) broadband ($\Delta\lambda$~200 nm) volume holographic grating pair can provide the required beam directing, focusing, spectrum splitting and recombination functions. Cascading such arrays for different (broad) spectral bands will allow scanning over a full wavelength range (visible to near IR). The two most essential components of the proposed sensor are the coupled grating pair which must be highly efficient and very broad-band, and the high resolution LC-SLM array. Both of these components are mainstream technologies. In Phase I, the primary design will be produced of a high resolution compact multiband MSIS system; the necessary fabrication techniques will be developed to produce a demonstration prototype system.

Anticipated Results / Potential Commercial Applications as described by the awardee: The proposed concept will lead to development of a new generation of highly versatile MSI sensors for remote sensing applications. The associated nanotechnology development can also be used for the production of compact, low cost sensors for biomedical spectroscopic imaging, laser radar, and optical communications applications.

INTERNATIONAL ATOMIC ENERGY AGENCY SPECIAL SAFEGUARDS INSPECTIONS

20

Improved Analytical Measurements to Monitor Nuclear Activities--Atom Sciences, Inc., 114 Ridgeway Center, Oak Ridge, TN 37830;
(615) 483-1113
Dr. George I. Bekov, Principal Investigator
Dr. William A. Gibson, Business Official
DOE Grant No. DE-FG05-94ER81659
Amount: $74,982

It is possible to ascertain the nature of nuclear activities, whether for power generation or weapons development, by determining the isotopic abundance of several actinide elements. Due to the extremely low concentration of these elements in environmental samples, and the short range of the decay products, alpha spectrometry requires very time consuming and labor intensive sample preparations. Thermal Atomization Resonance Ionization Spectroscopy (TARIS) offers the possibility of enhanced sensitivity over conventional analysis techniques (stable and radioactive isotopes) with little or no sample preparation. In the implementation of TARIS, the sample is thermally vaporized and then atomized on a separate, high-temperature surface. Tuned lasers are then used to efficiently ionize the analyte atoms while producing little ionization of the sample matrix, and isotopes are monitored in a time-of-flight mass spectrometer. This technique has the potential of vastly reducing sample preparation requirements and lowering detection limits by several orders of magnitude in measurements of ultra-trace concentrations of actinide isotopes from a wide variety of samples. Initial instrumentation has already demonstrated sub parts-per-trillion detection limits for platinum group elements in ocean water (using concentration techniques). The Phase I effort should demonstrate the technique for measurements of ultra-trace plutonium isotopes in previously characterized environmental samples, and assess the potential for sample preparation simplification. A prototype instrument optimized for trace actinide isotope measurements, together with simplified sample preparation protocols for specific safeguards measurements, will be developed during Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: The proposed instrumentation would provide improved sensitivity and significantly reduced sample preparation requirements, leading to more accurate laboratory analyses of smaller samples. This is important for the analysis of both overt and covert International Atomic Energy Agency samples, and a small number of instruments sales would be expected for this purpose. More importantly, from a commercial standpoint, would be the impact on a number of applications in a wide range of fields, such as semiconductor and materials science, biomedical sciences, and the environmental sciences.

21

A Handheld Cadmium Telluride Spectrometer for Nuclear Safeguards Inspections--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Dr. Michael R. Squillante, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-94ER81680
Amount: $75,000

The objective of this program is to develop a large volume, high resolution cadmium telluride (CdTe) detector and the required miniature electronics for use in a portable gamma ray spectrometer suitable for on-site nuclear safeguards inspections. The detector would use a stack of thin CdTe radiation detectors, in order to minimize charge collection losses, coupled to an electronic interface which minimizes the system noise. The spectrometer, including the detector, the pulse compensation circuitry, the multichannel analyzer, and a microprocessor-based interface can be placed in a package comparable in size and weight to present-day nuclear survey instruments. Such an instrument would have high energy resolution and high detection efficiency in a very portable, rugged package and would allow high resolution assays of radioactive material to be conducted in the field with great ease and reliability. This would significantly improve the credibility of the intrusive, on-site safeguard inspections by the International Atomic Energy Agency. The Phase I research involves fabricating and testing a stack of thin CdTe detectors to achieve large detection volume with high energy resolution and miniaturization of the associated electronics.

Anticipated Results / Potential Commercial Applications as described by the awardee: A gamma-ray spectrometer with high energy resolution and high detection efficiency in a very portable, rugged package would find widespread use throughout the nuclear industry. Applications include radioactive waste monitoring and cleanup, the verification of nuclear disarmament treaties, and routine operations at nuclear power plants.

22

A Document Imaging, Indexing, and Retrieval System for International Atomic Energy Agency Special Inspections--Stange Associates, 5853 Finecrest Drive, Rancho Palos Verdes, CA 90274; (310) 541-9574
Ms. Betty J. Chandler, Principal Investigator
Mr. L. G. Stange, Business Official
DOE Grant No. DE-FG03-94ER81683
Amount: $74,979

A computer automated data storage and retrieval system to serve as the central repository and analytical forum for International Atomic Energy Agency (IAEA) Special Inspections will be physically and functionally defined. Such an automated information management system is critical to the assimilation of the voluminous nuclear information (text, maps, diagrams, space sensor data, photographs, etc.) to support Special Inspection implementation. The technology, hardware, and software for this kind of system is largely available. The project at hand will tailor a system to the customer requirement, which is one that is inexpensive yet robust and scalable for application to a text base as small as a few thousand pages up to a million or more. The system will allow for the storage and indexing of existing paper files, the continued day-to-day entry of new documents into the data base, and the ability to acquire data remotely. Special emphasis is placed on low cost document scanning, optical character recognition, and image storage and retrieval. The Phase I project consists of eight tasks: requirements definition, system architecture, high volume imaging, desktop (day-to-day) imaging, field imaging, optical character recognition (OCR) software, compact disk-read only memory (CD-ROM) system, and indexing and retrieval. A complete system design, operations procedures, training requirements, cost-performance-size data and scaling factors for sizing the system, and estimated system performance data will be delivered.

Anticipated Results / Potential Commercial Applications as described by the awardee: An automated information storage and retrieval system tailored for IAEA Special Inspections will be developed. It will consist of a network of local and remote document imaging and character recognition workstations tied to a centralized indexing and retrieval data base. This scalable, paperless corporate information base will be adaptable to any size activity regardless of distribution of personnel. Portable data acquisition and retrieval capability using CD-ROM will allow remote operation where there is no outside world communication. Large complex systems are available for business and industry. This smaller, low cost, robust system will meet the requirement for many commercial applications in newspapers, publishing houses, portable geological information systems, and anywhere a small, flexible, distributed field portable system is indicated.

23

A Low-Cost, Remotely Operated, Safeguards Surveillance Satellite Communications Terminal--Tera Research Inc., 1344 Bordeaux Drive, Sunnyvale, CA 94089-1005; (408) 734-3096
Dr. Jack Liu, Principal Investigator
Mrs. Patricia K. Black, Business Official
DOE Grant No. DE-FG94-ER81685
Amount: $74,706

This project involves the design and development of a low-cost, remote surveillance and satellite communications (SATCOM) terminal to support International Atomic Energy Agency (IAEA) implementation of safeguards under the Non-Proliferation Treaty and the IAEA safeguards system as defined in INFCIRC/66. This system will enable remote monitoring of containment and surveillance measures that are part of safeguards measures at nuclear fuel cycle facilities. A satellite communications link will allow collected data to be passed frequently to IAEA headquarters in Vienna, Austria and improve detection timeliness. Modular design will result in a terminal that is inexpensive to procure and operate. It will effectively reduce the number of required routine inspections and thereby free up expensive IAEA inspection resources to address more critical special inspections. Phase I will focus on identifying and evaluating implementation alternatives for the remote SATCOM terminal, and a demonstration of the feasibility of the concept.

Anticipated Results / Potential Commercial Applications as described by the awardee: This effort will result in a low-cost, modular, remote data acquisition and control SATCOM terminal that can be configured to support a range of data collection and control applications. Low unit cost will make multiterminal access from different sites feasible. Its remote access feature will enable real-time control, monitoring, and reconfiguration of processes. Additional applications include mobile computer networks, military telecommunications networks, wildlife and resource monitoring, and managing widely dispersed systems such as pipeline networks.

TECHNOLOGIES FOR DOMESTIC NONPROLIFERATION AND SAFEGUARDS

24

A Micro Pyrovidicon: An Infrared Imaging Device for Intrusion Detection--Advanced Technology Materials, Inc., 7 Commerce Drive, Danbury, CT 06810; (203) 794-1100
Dr. Galina Doubinina, Principal Investigator
Mr. Daniel P. Sharkey, Business Official
DOE Grant No. DE-FG05-94ER81655
Amount: $75,000

An ideal intrusion detection system would allow intruders to be detected and identified by a minimal number of sensors. Infrared (IR) imaging could accomplish these goals if a compact, low cost, low maintenance IR imager can be built and deployed. The sensitivity of the imager would need to be high so that distinctive features of intruders can be captured for use as identity markers and for discriminating between actual and false alarms. Very sensitive detectors made of gallium arsenide and mercury cadmium telluride are used for tracking hot objects or for high resolution imaging. The major drawback of devices fabricated from these materials is that they require low temperature cooling to achieve high sensitivity. A new compact IR imaging system is proposed which eliminates the need for refrigeration while maintaining high performance. The proposed system is based on a micro pyrovidicon vacuum tube array fabricated by micromachining techniques. The high resolution, small size, low weight, and low power consumption of the proposed imaging system coupled with the high reliability and potentially low cost of volume semiconductor manufacture make the micro pyrovidicon array an ideal choice for use in remote intrusion detection systems. Phase I should demonstrate the feasibility of constructing vacuum micro pyrovidicon single pixel and of electron beam read out of pyroelectric charge in the micro device.

Anticipated Results / Potential Commercial Applications as described by the awardee: The proposed micro pyrovidicon can be used in a variety of fields: (1) in medicine to obtain thermal images of sick organs which usually have higher than normal temperature in the body, (2) in the semiconductor industry to check for defective components, (3) to control working engines, where the thermal picture can be used to find trouble spots, (4) to check high-voltage switches, where higher temperature indicates when they are approaching breakdown, (5) for night vision to see fine details like face features, and (6) in defense, for missile warning and tracking.

25

Room-Temperature Gamma-Ray Spectrometers--
Detectronics, 2517 Regent Road, Livermore, CA 94550;
(510) 455-6520
Mr. Ching Lin Wang, Principal Investigator
Dr. Helen F. Wang, Business Official
DOE Grant No. DE-FG03-94ER81663
Amount: $73,241

Currently, a sodium iodide (NaI) scintillator or germanium (Ge) semiconductor is used to measure the gamma spectrum to assay low-grade radioactive materials in waste or in process equipment at DOE facilities. NaI crystals have poor spectral resolution while Ge detectors must be cooled, making them too heavy to carry. This project will study the development of room-temperature semiconductor gamma-ray detectors with energy resolution better than that of the NaI detector. These semiconductor detectors are small but efficient and can be "handheld". They can therefore decrease the size and weight of the portable measurement systems that are used during the DOE facility transitions and cleanup activities. The difficulty associated with semiconductors of medium and higher atomic numbers with wide enough bandgap for room temperature operation is that they all suffer from short carrier drift length. These detectors can be made small with good energy resolution but poor detection efficiency, or they can be made larger with better detection efficiency but poorer energy resolution. Good energy resolution and good detection efficiency are mutually exclusive for crystals with short carrier drift length. This project is designed to overcome this difficulty by distributing narrowly spaced hairline electrodes throughout the crystals to collect charge carriers before they disappear, and to establish a new method for building room-temperature gamma-ray spectrometers of moderate energy resolution and high detection efficiency. In Phase I, simplified prototype detectors will be designed and fabricated, tested with radioactive sources, and their performance analyzed by Monte Carlo calculations.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project could open the door for building room-temperature gamma-ray spectrometers of medium energy resolution and high detection efficiency, with markets in the basic as well as applied research communities. The users would include atomic and nuclear physics experimenters, International Atomic Energy Agency nuclear verification inspectors, domestic nonproliferation and safeguard personnel, DOE facility transition and cleanup teams, biomedical researchers, and substance enforcement agencies.

26

An Intelligent Intrusion Detection System--
Halberd, 477 West 5200 North, Park City, UT 84060;
(801) 640-0246
Dr. Donald L. Chaffee, Principal Investigator
Dr. Donald L. Chaffee, Business Official
DOE Grant No. DE-FG02-94ER81668
Amount: $74,760

This project addresses the development of a low cost approach for intrusion detection. The system concept is to create a packet radio network that would connect a group of sensor packages. Each sensor package will contain a set of physical sensors. Multisensor data fusion will be done by a microprocessor within each sensor package using data from the sensors within the package. Using radio communications, the sensor packages in a detection zone will perform zone-wide sensor data fusion which will provide the intrusion alarm. The project directly addresses the use of adaptive fuzzy systems for multisensor data fusion. Further, the selection and use of sensors that can provide means of automatic initialization and self-check are sought. Costs of system acquisition, initialization, and maintenance will be drastically reduced by the use of multiple cooperating sensor packages, deployment scenarios, and machine intelligent learning. A packet radio network with an artificially intelligent router will be part of the system. Spread spectrum radios are used for low probability-of-intercept operations. The possibility of using the spread spectrum radios as a bistatic radar sensor will be explored. The primary objective of Phase I is to demonstrate the feasibility of a systems approach to the selection of sensors, multisensor data fusion, and learning feedback scenarios.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will result in a product that can provide low cost intrusion detection aids to guarded facilities, a subsystem component to augment security systems with more expensive equipment and site preparation, and a rapidly deployable and easily relocatable intrusion detection system.

27

Development of a Holographic Verification Tag for Secure Inventory--MetroLaser, 18006 Skypark Circle, Suite 108, Irvine, CA 92714; (714) 553-0688
Dr. James. D. Trolinger, Principal Investigator
Dr. Cecil F. Hess, Business Official
DOE Grant No. DE-FG03-94ER81672
Amount: $74,874

New verification, inspection, and monitoring technologies and methods are needed to accurately and efficiently protect and control assets and information throughout the Department of Energy. Holographic anti-counterfeiting technology, which has saved many millions of dollars in the credit card and other industries can be expanded to fulfill this need. This project will develop a new and unique holographic identification mark that cannot be removed, reproduced, or transferred covertly. The mark will be covertly readable from a distance, allowing verification of a component as the one and only previously marked original. Such components cannot be covertly reproduced, duplicated, or replaced and any component not containing such a label can be easily identified. Holographic verification technology also prevents the replacement of the originally labeled component with modified or improved components. The Phase I project will include studies of the application of photopolymer material to surfaces of interest, the construction of the hologram, and possible methods for inserting image data into the hologram.

Anticipated Results / Potential Commercial Applications as described by the awardee: Holographic verification and anti-counterfeiting technology saves many millions of dollars each year. As counterfeiters become more sophisticated, higher levels of verification will be required. The proposed technique will address such markets. A secure credential or verification mark which is a one and only original can provide a solution to the most advanced attempts to prevent accurate verification.

28

An Intelligent Intrusion Detection System Using a Fiber Optic Sensing Network--Optiphase, Inc., 7652 Haskell Avenue, Van Nuys, CA 91406-2005; (818) 782-0997
Mr. Ira Jeffrey Bush, Principal Investigator
Mr. Ira Jeffrey Bush, Business Official
DOE Grant No. DE-FG03-94ER81675
Amount: $75,000

Conventional technology intrusion detection systems that monitor large "secure" areas are often prone to generating false and "nuisance" alarms. These false alarms typically result from some environmental change independent of the intruder, and could be prevented if sensors used in the intrusion detection system were capable of measuring and transmitting high resolution information to a central processing system. This processing system would perform high level analysis to weed out only true intrusion events. For such an "intelligent" intrusion system to be feasible, it would have to employ high resolution analog sensors of different types that are low in cost and easily deployed. There are currently in existence electronic, electro-mechanical, and electro-optical sensors which, if independently operated, have this capability. It is, however, extremely difficult, expensive (or both) to transmit the electronic data by telemetry from many sensors to a central location. This project addresses a new type of sensing approach, which uses passive (non-electric) fiber optic components to comprise both the sensors and the data telemetry highway. The unique aspects of the project involve the use of low loss optical fiber (for very large area coverage); interferometric sensors (for high resolution), which can be configured to detect many different types of environmental stimuli; and a time domain multiplexed interrogation approach which is used to monitor hundreds of sensors. This proposed fiber optic sensing network concept has the potential of high accuracy, simple deployment, and low life-cycle costs. In Phase I, design analysis will be performed to identify appropriate performance characteristics and required operating parameters that serve to minimize or eliminate false intrusion alarms. Also in Phase I, a "proof of concept" fiber optic sensor system will be fabricated and evaluated. A fully field-worthy prototype intelligent intrusion detection system is scheduled for development in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: The proposed fiber optic sensing approach directly addresses an unlimited number of commercial applications, where low price, ease of deployment, high accuracy, and immunity to electromagnetic interference are required. Commercial applications could include factory, office, and home security systems; countless areas in industrial process control (factory automation); towed acoustic sensing arrays for seismic exploration and large land area seismic monitoring; and smart skins for commercial vehicles and structures.

29

A Miniature Charge Sensitive Preamplifier Using Pulsed Drain Feedback--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Mr. James C. Lund, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-94ER81679
Amount: $75,000

A new type of charge sensitive preamplifier will be investigated for use in portable measurement systems which is small in size, has very low noise properties, yet is very simple to configure with any type of detector. Specifically, this project will investigate pulsed drain-feedback charge-sensitive preamplifiers for use with miniaturized gamma-ray spectrometer equipment. The proposed preamplifier works well with many types of high resolution detector systems and does not require special components. The lack of optical components in the design would allow the circuit to be mass-manufactured in a miniaturized version to reduce its cost and size. As a result, the proposed miniature preamplifier will be able to directly replace optical reset preamplifiers found in germanium detector systems. In addition, this replacement will allow gamma-ray spectrometer systems to maintain excellent energy resolution at count rates higher than normally possible with optical reset electronics. The Phase I research should demonstrate that a versatile, low noise charge-sensitive preamplifier can be built having an all-electronic design (no optical components).

Anticipated Results / Potential Commercial Applications as described by the awardee: The eventual goal of the program is to develop the preamplifier, which will use a little-known technique known as drain feedback, in a highly miniaturized state for use with miniature gamma-ray spectrometer systems.

30

Development of an Automated Radio Frequency Tagging Method for Tamper Protected Inventory Control of Special Nuclear Material Containers--RAND Technologies Corporation, 9461-B Silver King Court, Fairfax, VA 22031; (703) 352-0833
Mr. Alan C. Hurkamp, Principal Investigator
Mr. Donald K. Salmon, Business Official
DOE Grant No. DE-FG05-94ER81681
Amount: $74,898

The Department of Energy requires an effective and affordable system for the protection of Special Nuclear Material (SNM) containers stored in vaults at its major storage sites. Such a system must be capable of providing an automated means for conducting a periodic inventory that will positively account for each container within a vault while providing for continuous tamper protection against a variety of threats including those from knowledgeable insiders. With technical assistance provided by Sandia National Laboratories, this project will develop and test key elements of an automated radio frequency (RF) tag polling system concept. The major benefits of this approach include a positive means of inventory control and added security protection, while eliminating the need for human exposure to hazardous radiation within a vault. Sandia will provide details of specifications and system protocols and their experience in pursuing similar goals; this project will continue the development of the RF tag polling concept. The major effort under Phase I will include the further definition of the system concepts and testing to refine technical parameters and critical components. Sandia will provide technical guidance and assistance with interfaces to existing systems.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is expected that the RF tag polling concept will be confirmed to be an effective means of automated SNM inventory control. In addition, it is anticipated that the tests and analyses performed during Phase I will lead to parameter and component selections that will result in a practical and affordable system design. Many elements of this design should have commercial potential in applications requiring the positive control of valuable and/or hazardous items of material.

31

RENAM: A Radio Frequency Identification Asset Management System for Nuclear Materials--Synetics Corporation, 540 Edgewater Drive, Wakefield, MA 01880; (617) 245-9090
Dr. Richard L. Smith, Principal Investigator
Mr. Bahar Uttam, Business Official
DOE Grant No. DE-FG02-94ER81684
Amount: $74,964

In Phase I, a turnkey system (RENAM) will be designed which could automatically and remotely track the movement of mobile assets; take inventory of assets stored in specific facilities; and detect and report tampering to containers within the facility. The operation will not require entry into the storage facility or any other manual action to enter data into the system, resulting in increased security with large labor savings and a decrease of exposure of workers to potentially hazardous conditions within the storage area. The particular assets to be tracked for the DOE are containers of Special Nuclear Materials, but the system will be capable of tracking any asset. The system uses a radio frequency identification device with a capability to interact with additional sensors to provide a non-contact method to remotely identify assets and communicate data. RENAM will be designed so that it can be installed either as a stand-alone system or can be completely integrated with the existing materials accounting system in use at DOE sites. All interactions with the system will be through graphical user interfaces and will pictorially depict the layout of each site and facilities. Special attention will be taken to determine the functional and user interface requirements that are needed to comply with existing procedures and processes, policies, and security requirements at the intended site locations. A demonstration prototype system will be developed both to illustrate the system's capabilities and to detect any additional development items which might not arise in a paper study.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phases II and III would produce a turnkey asset management system to remotely track, take inventory, and detect tampering and pilferage for highly mobile or fixed items. This capability would be an innovative, cost-effective solution useful throughout a wide range of industries, business, and all levels of government. The system could be used by itself or interfaced with extant materials accounting systems. It utilizes commercially available hardware and computing components to provide an inexpensive system. Greatly increased security, traceability, and tamper detection would be provided while decreasing the required labor time.

32

An Ultra-Compact Cesium Iodide/Mercuric Iodide Gamma-Ray Scintillation Spectrometer--Xsirius, Inc., 1220 Avenida Acaso, Camarillo, CA 93012; (805) 484-8300
Dr. Bradley E. Patt, Principal Investigator
Dr. Jan S. Iwanczyk, Business Official
DOE Grant No. DE-FG03-94ER81687
Amount: $74,016

The goal of this project is the use of a novel semiconductor photodetector utilizing large mercuric iodide photodetectors coupled to highly optimized cesium iodide (thallium) (CsI(Tl)) scintillators that will both increase the energy resolution and decrease the size and weight of detector systems assembled as the ultra-compact hand held units for assaying low-grade radioactive materials to facilitate cleanup activities and facility transition. This effort is motivated by the limitations such as inferior energy resolution for photomultiplier tubes (PMTs) and silicon devices, and by disadvantages such as large size, voltage regulation required, and magnetic field sensitivity for PMTs, and by the bulky apparatus associated with cryogenic cooling for direct gamma-detectors such as germanium. Recently fabricated 1/2-inch diameter cesium iodide/mercuric iodide (CsI/HgI_2) scintillator pairs have produced better and more reproducible results than ever reported for room temperature scintillation spectroscopy. Additionally, HgI_2 semiconductor photodetectors can enable extremely compact and rugged geometry and packaging. The Phase I work will include the selection of an appropriate HgI_2 crystalline material grown in a crystal laboratory, and the fabrication of large-area photodetectors with diameters from 1 to 2 inches using a new structure that will optimize the geometry, packaging, and coupling of the scintillator crystals for compactness, efficiency, and light collection. Scintillator/photodetector pairs will be constructed based on these designs, and evaluated in the laboratory using optimized preamplification electronics. Finally, the feasibility of these detectors will be tested for use in nondestructive assay by making realistic measurements of Special Nuclear Material at Sandia National Laboratory. A successful Phase I effort will resolve all of the questions concerning the implementation of the new devices as the detector in new ultra-compact, high-resolution scintillation spectrometers. A prototype spectrometer using this technology will then be fabricated in a future Phase II effort. The novel new detector can eventually become a PMT replacement with widespread use in a large number of terrestrial and space applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: A successful Phase I effort will resolve the issues concerning the viability of large-area (1 to 2 inch) HgI_2 photodetectors for use in high resolution, compact scintillation spectrometers. This will be the critical component enabling the design, fabrication, and assembly in Phase II of a prototype, fieldable, ultra-compact scintillation spectrometer for facilities cleanup and transition. Such devices are sought throughout the gamma-ray spectroscopy community and would find widespread use in space/vacuum instruments, high energy physics research, health physics, personnel monitoring, medical research, and other commercial applications.

APPENDIX A

Alphabetical List of Awardees

Advanced Technology Materials, Inc. ***24***
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7 Commerce Drive
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(203) 794-1100

ALEM Associates ***1***
Dr. Alexander Lempicki, Business Official
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ANDCARE, Inc. ***2***
Mrs. Carolyn J. Henkens, Business Official
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Atlantic Aerospace Electronics Corporation ***17***
Dr. Theodore Bially, Business Official
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Atom Sciences, Inc. ***20***
Dr. William A. Gibson, Business Official
114 Ridgeway Center
Oak Ridge, TN 37830
(615) 483-1113

Bend Research, Inc. ***13***
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Covalent Associates, Inc. ***3***
Dr. Victor R. Koch, Business Official
10 State Street
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(617) 938-1140

Detectronics ***25***
Dr. Helen F. Wang, Business Official
2517 Regent Road
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Engineering Resources, Inc. ***9***
Mr. S. S. Adams, Business Official
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ENVIROGEN, Inc. ***15***
Mr. William J. Guarini, Business Official
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Environmental Risk Limited ***10***
Dr. Gordon T. Brookman, Business Official
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Foster-Miller, Inc. ***14***
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Halberd ***26***
Mr. Donald L. Chaffee, Business Official
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ICET, Inc. ***4***
Dr. S. Sarangapani, Business Official
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References denote entry numbers

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Dr. John Kevin Markey, Business Official
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MetroLaser *27*
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18006 Skypark Circle, Suite 108
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Microsensor Systems, Inc. *6*
Dr. Hank Wohltjen, Business Official
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Mission Research Corporation *18*
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Optiphase, Inc. *28*
Mr. Ira Jeffrey Bush, Business Official
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Physical Optics Corporation *12, 19*
Ms. Patty Shaw, Business Official
2545 West 237th Street, Suite B
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Physical Sciences, Inc. *7*
Mr. George E. Caledonia, Business Official
20 New England Business Center
Andover, MA 01810-1077
(508) 689-0003

Radiation Monitoring Devices, Inc. *21, 29*
Dr. Gerald Entine, Business Official
44 Hunt Street
Watertown, MA 02172
(617) 926-1167

RAND Technologies Corporation *30*
Mr. Donald K. Salmon, Business Official
9461-B Silver King Court
Fairfax, VA 22031
(703) 352-0833

Research International, Inc. *8*
Ms. Joyce M. Brien, Business Official
18706 142nd Avenue, NE
Woodinville, WA 98072
(206) 486-7831

Stange Associates *22*
Mr. L. G. Stange, Business Official
5853 Finecrest Drive
Rancho Palos Verdes, CA 90274
(310) 541-9574

Synetics Corporation *31*
Mr. Bahar Uttam, Business Official
540 Edgewater Drive
Wakefield, MA 01880
(617) 245-9090

Tera Research, Inc. *23*
Mrs. Patricia K. Black, Business Official
1344 Bordeaux Drive
Sunnyvale, CA 94089-1005
(408) 734-3096

TPL, Inc. *16*
Mrs. Caroline F. Eisenhood, Business Official
3768 A/B Hawkins, NE
Albuquerque, NM 87109
(505) 344-6744

Xsirius, Inc. *32*
Dr. Jan S. Iwanczyk, Business Official
1220 Avenida Acaso
Camarillo, CA 93012
(805) 484-8300

References denote entry numbers

APPENDIX B

State List of Awardees

Arkansas	9
California	12, 18, 19, 22, 23, 25, 27, 28, 32
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New Mexico	11, 16
North Carolina	2
Oregon	13
Tennessee	20
Utah	26
Virginia	30
Washington	8

References denote entry numbers

APPENDIX C

Grant Application Submissions and Awards
Listed by States, Territories, and Possessions

State	Number Submitted	Number Selected	State	Number Submitted	Number Selected
Alabama	10	0	Montana	7	0
Arizona	13	0	Nevada	5	0
Arkansas	2	1	New Jersey	31	1
California	89	9	New Mexico	29	2
Colorado	19	0	New York	16	0
Connecticut	14	3	North Carolina	4	1
District of Columbia	1	0	Ohio	10	0
Florida	17	0	Oklahoma	2	0
Georgia	7	0	Oregon	2	1
Illinois	12	0	Pennsylvania	20	0
Indiana	1	0	Rhode Island	1	0
Iowa	4	0	South Carolina	1	0
Kansas	1	0	Tennessee	8	1
Kentucky	4	1	Texas	23	0
Louisiana	19	0	Utah	13	1
Maine	1	0	Vermont	1	0
Maryland	18	0	Virginia	23	1
Massachusetts	54	9	Washington	9	1
Michigan	5	0	West Virginia	1	0
Minnesota	5	0	Wisconsin	4	0
Missouri	1	0	Wyoming	2	0

Although eligible in each case to participate, there were no submissions from Alaska, Delaware, Hawaii, Idaho, Mississippi, Nebraska, New Hampshire, North Dakota, South Dakota, Puerto Rico, the Virgin Islands, the Commonwealth of the Northern Mariana Islands, or the Trust Territory of the Pacific Islands.

APPENDIX D

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Sequential extraction 10
Solvent extraction 13
Thermal imaging 24
Volatile organic compound contamination 15
Waste stream diagnostics 12

References denote entry numbers

SELECTION STATEMENT FOR PHASE I AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM FOR FISCAL YEAR 1994 (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0598)

U. S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585
JUNE 30, 1994

SELECTION OF GRANT APPLICATIONS FOR NEGOTIATION OF SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM PROJECTS FOR FISCAL YEAR 1994 UNDER PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0598

As a former chairman of the SBIR Application Score Verification Panel appointed to evaluate Phase I applications for the SBIR program, I am familiar with the Panel's evaluation procedures and its methodology. I have received reports from the Technical Topic Managers (TTMs) who were responsible for the review of the 43 technical topic areas listed in the solicitation. I believe that the Panel and the TTMs have proceeded in accordance with applicable laws and regulations, that the evaluation has been thorough and equitable, and that the information presented forms a sound basis for selection. Consequently, I have selected 216 applications received under this solicitation for negotiation for award of Phase I Fiscal Year (FY) 1994 SBIR grants. This statement describes the procurement and sets forth the basis for my selection decision.

Procurement Description

The Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564), requires that each Federal agency with an extramural research or research and development budget exceeding $100 million establish an SBIR program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies over the 18 years of the program are as follows:

Fiscal Year	SBIR Set Aside (%))
1983	0.2
1984	0.6
1985	1.0
1986-1992	1.25
1993-1994	1.5
1995-1996	2.0
1997-2000	2.5

Public Laws 97-219 and 102-564 also prescribe that the SBIR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the SBIR program. This phase will have a period of performance which is typically six months in duration. Awards will be up to $75,000 for FY 1994 Phase I projects. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $750,000 for FY 1995 Phase II projects. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-SBIR funded Federal contracts for products or services intended for use by the U.S. Government.

In response to the first twelve program solicitations for FY 1983-1993, DOE received a total of 14,452 Phase I proposals. Of these proposals, 1,553 resulted in Phase I contracts or grants, and of these 636 were subsequently selected for Phase II awards. The results of the 1994 Phase I grant applications discussed here will be added to the above figures which demonstrate the high level of volume and interest in the SBIR program.

Applications Received

Outreach efforts for the DOE SBIR program were considerable. DOE mailed out approximately 30,000 1994 solicitations to past recipients on an extensive mailing list and to other individuals requesting copies. In addition, the SBIR solicitation was advertised in the Commerce Business Daily on October 28, 1993. It also received coverage in trade journals and newsletters and in various Small Business Administration information releases and conferences.

A total of 2,276 applications were received in response to the solicitation. The solicitation listed 43 technical topic areas to which applicants could respond. The list of technical topic areas and the number of applications received in each area are as follows:

1.	Engineering Advances for Photovoltaic Systems	61
2.	Fuel Cells for Transportation	46
3.	Improved Formability of Magnesium Alloys for Automotive Applications	22
4.	Industrialized Passive Solar Buildings	68
5.	Wind Turbines: Efficiency Improvement Using Advanced Power Electronics	53
6.	On-Site Remediation of Contaminated Media	100
7.	Expedited Waste Site Characterization	114
8.	Low-Level Mixed Waste Processing	60
9.	Chemical Separation Processes for Waste Treatment	42
10.	Arms Control and Nonproliferation Verification and Detection Technology	30
11.	International Atomic Energy Agency Special Safeguards Inspections	28
12.	Innovative Fossil Solids and Liquids Processing and Related Crosscutting Applications	120
13.	Advanced Environmental Control Technology for Fossil Energy	137
14.	Advanced Technology for the Recovery, Storage, and Utilization of Natural Gas	111
15.	Coal-Based Power Systems Technology	52
16.	Enhanced Oil Recovery	43
17.	Robots for Nuclear Environments	66
18.	Technology for Space Nuclear Propulsion and Power	59
19.	Technology to Support and Improve Nuclear Fuel Cycle Processes	15
20.	Measurement of Mechanical Properties in Civilian Nuclear Reactor Facilities	26

21.	Personal Monitoring for Particulates	8
22.	Educational Technology: Electronic Game Devices for Mathematics, Science, and Engineering	68
23.	Green Car: Scientific Approaches to Automotive Innovations	189
24.	Design and Applications of Novel Materials	117
25.	Materials Sciences Instrumentation	36
26.	Improved Onstream Methods of Nondestructive Evaluation	23
27.	Advanced Geophysical Imaging in Geosciences Research	31
28.	Chemical Sciences Research	80
29.	High Performance Computing Research	30
30.	Atmospheric Measurement and Sampling Technologies	36
31.	Bacterial Identification and Sampling	8
32.	Health Effects	6
33.	Human Genome	32
34.	Medical Applications	66
35.	Plasma Confinement Systems Technology	56
36.	Fusion Energy Systems	12
37.	Plasma Diagnostics	26
38.	Technology and Instrumentation for Heavy Ion Fusion Accelerators	9
39.	Nuclear and High Energy Physics Educational Devices	40
40.	Technology and Instrumentation for High Energy Accelerators	53
41.	High Energy Physics Data Processing and Detector Instrumentation	26
42.	Nuclear Physics Instrumentation and Techniques	49
43.	Nuclear Physics Accelerator Technology	17

Five applications received could not be assigned to a specific topic or subtopic.

Of the 2,276 applications received, 77 were eliminated for administrative reasons; DOE staff determined that these applications failed to meet one or more material requirements of the solicitation. Two applications were withdrawn by the proposing firms.

The remaining 2,197 were judged on a competitive basis in a two-step process. The first step of that process was a screening by the TTMs and DOE staff knowledgeable in the topic area to determine the relevance of each application to a chosen topic by the extent to which it responded to a specific topic area. Then it was determined whether each application was for research or research and development, whether it provided sufficient information for a full evaluation, whether it was duplicative of other ongoing or previous efforts, and finally, whether it was of sufficiently high quality for award. One thousand forty-seven applications were eliminated after the first step technical review. The 1,150 applications found to be relevant were evaluated in the second step according to criteria listed in the solicitation and set out below.

Selection Criteria and Rationale

Phase I awards were made on scientific and technical merit based upon the criteria listed below. Approximately equal consideration was given to each of the following criteria:

(1) The scientific/technical quality of the research in the Phase I grant application.

(2) The degree of innovation demonstrated by the grant application.

(3) The qualifications of the Principal Investigator, other key staff, and consultants, if any, and the level of adequacy of available or obtainable instrumentation and facilities.

(4) The anticipated benefits, technical and/or economic, of the proposed research (Phase I and Phase II), if successful, with special emphasis on the likelihood that the project will attract further funding for product or process development after the SBIR support expires.

(5) The soundness and level of adequacy of the Phase I proposed work plan to show progress toward proving the feasibility of the concept.

For each of the 43 technical topic areas listed in the solicitation, there was a TTM who, along with reviewers both internal to DOE and external - selected from among DOE Laboratory personnel, university researchers, and private industry personnel - evaluated and scored applications against the assigned criteria. An Application Score Verification Panel (ASVP) consisting of technical staff from both within and without DOE was established to ensure relative uniformity of scoring across the 43 topic areas and to ensure that scores were based on meaningful technical reviews. The ASVP was also chartered to ensure that there was consistency of scoring within topics.

I have examined the evaluation documentation presented by the TTMs. I have also carefully reviewed the recommendations of the ASVP and have agreed that the evaluations of the TTMs and the recommendations of the ASVP provided valid bases upon which to make a selection. Therefore, based on those recommendations, and in consideration of applications whose funding would contribute to a programmatically-balanced set of SBIR-supported projects, I have selected 216 applications for negotiations. Included in these are all applications which received the highest possible technical rating or were within one point of such a rating. The remainder was selected from among applications that were rated two points below the highest possible technical rating, on the basis of (1) program balance and (2) the amount of Phase III funding received for previous DOE SBIR Phase II projects. It is my view that these applications represent outstanding technical quality and are worthy of selection for this program.

Selected Applications

Appendix A is a listing of the applications selected for negotiations leading to award. The SBIR program is an ongoing one, and continued participation in later solicitations is strongly encouraged.

Samuel J. Barish

Samuel J. Barish
SBIR Program Manager

Date: 6/30/94

Attachment:
List of Grant Applications
Recommended for Awards

APPENDIX A
DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1994 AWARDS

TOPIC: ENGINEERING ADVANCES FOR PHOTOVOLTAIC SYSTEMS

Abacus Controls, Inc. 80 Readington Road Somerville, NJ 08876	A Trimode Power Processor to Optimize Photovoltaic, Battery, and Diesel-Generator Sources for Economic Stand-Alone Power Plants
AstroPower, Inc. Solar Park Newark, DE 19716	High Speed Sheet Growth of Thin Silicon Films
AstroPower, Inc. Solar Park Newark, DE 19716	Low Cost, High Purity Silicon by Alkaline Glycolic Digestion of Silica
Electronic Power Conditioning, Inc. 1895 Northwest Ninth Street Suite A Corvallis, OR 97330	A Resonant Converter for Photovoltaic Systems
Energy Conversion Devices, Inc. 1675 West Maple Road Troy, MI 48084	A Photovoltaic Wire Grid Design and Process
Energy Photovoltaics, Inc. 276 Bakers Basin Road Lawrenceville, NJ 08648	Monolithic Integration of Thin Film Photovoltaics on Insulated Metal Substrates
Evergreen Solar Company 107 York Terrace Brookline, MA 02146	A Novel Interconnect Scheme for Photovoltaic Modules
International Solar Electric Technology 8635 Aviation Boulevard Inglewood, CA 90301	An Innovative Approach for Large Area Photovoltaic Material Processing
Solar Design Associates P.O. Box 242 Harvard, MA 01451-0242	A 50 Watt DC-AC Inverter for Stand-Alone and Grid-Connected Photovoltaic Applications

Solar Engineering Applications Corporation P.O. Box 62246 Sunnyvale, CA 94088	Low Cost Solar Cell Leads for Use in Photovoltaic Modules
Spire Corporation One Patriots Park Bedford, MA 01730-2396	Very Low-Cost/High-Efficiency Thin-Film Silicon Photovoltaic Technology
SunPower Corporation 435 Indio Way Sunnyvale, CA 94086	Development of a Low Cost High Concentration Photovoltaic Dense Array Module for Use with Reflective Concentrators

TOPIC: FUEL CELLS FOR TRANSPORTATION

Arcanum Corporation P.O. Box 1482 Ann Arbor, MI 48106	Improved Activated Carbon for Hydrogen Storage
ElectroChem, Inc. 400 West Cummings Park Woburn, MA 01801	Non-Precious Metal Catalysts for Proton Exchange Membrane Fuel Cells by Ion Beam Synthesis
ICET, Inc. 916 Pleasant Street Unit 12 Norwood, MA 02062	Contamination Tolerant Anodes for Polymer Electrolyte Membrane Fuel Cells
Lynntech, Inc. 7610 Eastmark Drive Suite 105 College Station, TX 77840	Contamination-Tolerant Anodes for Proton Exchange Membrane Fuel Cells
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	Metal Carbide Nanoclusters for Polymer Electrolyte Membrane Fuel Cells

TOPIC: IMPROVED FORMABILITY OF MAGNESIUM ALLOYS FOR AUTOMOTIVE APPLICATIONS

Chesapeake Composites Corporation 239 Old Churchman's Road New Castle, DE 19720	A Superplastic Oxide Dispersion Strengthened Magnesium Alloy for Automotive Applications

TOPIC: INDUSTRIALIZED PASSIVE SOLAR BUILDINGS

Aspen Systems, Inc. 184 Cedar Hill Street Marlborough, MA 01752	Modular/Transportable Classroom Structures
Modern Building Systems, Inc. P.O. Box 9493 Porter Road Aumsville, OR 97325	Design and Evaluation of Energy Efficient Modular Classroom Structures
Physical Optics Corporation 2545 West 237th Street Suite B Torrance, CA 90505	An Integrated Anamorphic Daylighting Roof Aperture (ADRA) System Based on Non-Imaging Optical Components
Steven Winter Associates, Inc. 50 Washington Street Norwalk, CT 06854	Design of a Family of Advanced Prototype Passive-Solar Modular Classrooms

TOPIC: WIND TURBINES: EFFICIENCY IMPROVEMENT USING ADVANCED POWER ELECTRONICS

AeroVironment, Inc. 222 East Huntington Drive Monrovia, CA 91016	A Look-Ahead Adaptive Control System (LACS) for Wind Turbine Generators
Electronic Power Conditioning, Inc. 1895 Northwest Ninth Street Suite A Corvallis, OR 97330	A Versatile, Technically Accessible Wind Turbine Controller
Electronic Power Conditioning, Inc. 1895 Northwest Ninth Street Suite A Corvallis, OR 97330	A Resonant Converter for Universal Wind Application
R. Lynette and Associates, Inc. 15042 Northeast 40th Street Suite 206 Redmond, WA 98052-5353	Wind Turbine Power Electronics with Hybrid Integrated Circuits

TOPIC: ON-SITE REMEDIATION OF CONTAMINATED MEDIA

ADA Technologies, Inc. 304 Inverness Way South Suite 110 Englewood, CO 80112	Removal and Recovery of Mercury from Contaminated Waters
Apogee Corporation 2501 North Loop Drive Ames, IA 50010	A Continuous High-Capacity Water Treatment Process for the Recovery of Heavy Metals
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	A Biopolymer Based Selective Barrier for the Containment of Groundwater Contaminants
TPL, Inc. 3768 A/B Hawkins, Northeast Albuquerque, NM 87109	Heavy Metal Remediation of Soil Using Permeable Chelation Barriers

TOPIC: EXPEDITED WASTE SITE CHARACTERIZATION

Applied Research Associates, Inc. Box 102A, Waterman Road South Royalton, VT 05068	Development of Penetration Enhancement for the Cone Penetrometer Using Sonic Drilling Technology
Aurora Technologies Corporation 7408 Trade Street San Diego, CA 92121-2410	A New Semiconductor Radiation Sensor for Expedited Waste Site Characterization
Berkeley MicroInstruments, Inc. 1301 South 46th Street Building 164 Richmond, CA 94804	A Micromachined Chemical Analysis System for Waste Site Characterization
Consultants for Environment System Technologies 10 Damara Street Irvine, CA 92714	A Personal Computer Window-Based Systematic Hazardous Waste Management Evaluator (SHOWME) for Waste Site Data Processing
ISOTRON Corporation 13152 Chef Menteur Highway New Orleans, LA 70129	Electrocore Electrokinetic Core Sampling and Monitoring

TOPIC: LOW-LEVEL MIXED WASTE PROCESSING

Biode, Inc. 2 Oakwood Road Cape Elizabeth, ME 04107	An Acoustic Plate Mode Aqueous Mercury Sensor
Spectral Sciences, Inc. 99 South Bedford Street, #7 Burlington, MA 01803-5169	An Off-Line-Locked Laser Diode Sensor (OLDS)

TOPIC: ARMS CONTROL AND NONPROLIFERATION VERIFICATION AND DETECTION TECHNOLOGY

Deacon Research 2440 Embarcadero Way Palo Alto, CA 94303	Microdevices for Proliferation Detection
ENSCO, Inc. 5400 Port Royal Road Springfield, VA 22151-2301	Human Presence Detection in Vehicles
ENSCO, Inc. 5400 Port Royal Road Springfield, VA 22151-2301	Reliable Intrusion Detection
Physical Optics Corporation 2545 West 237th Street Suite B Torrance, CA 90501	Human Presence Detection Based on Imaging Sensors and Image Processing and Analysis
Spectrum Data, Inc. P.O. Box 3100 Kent, WA 98032	Security Monitoring Systems: Sensors, Communications, and Computing
TeleRobotics International, Inc. 7325 Oak Ridge Highway Knoxville, TN 37931	Detecting Human Presence Using Synchronized Omnidirectional Video and Thermal Imaging
Utah Geophysical, Inc. P.O. Box 9344 Salt Lake City, UT 84109	Siesmic Detection of Individuals Hiding in a Vehicle

TOPIC: INTERNATIONAL ATOMIC ENERGY AGENCY SPECIAL SAFEGUARDS INSPECTIONS

Apfel Enterprises, Inc. 25 Science Park Suite 676 New Haven, CT 06511	Plutonium Assay Using Superheated Drop Technology in Support of International Atomic Energy Agency Safeguards
Spire Corporation One Patriots Park Bedford, MA 01730-2396	High Energy Resolution Cadmium-Zinc-Telluride Semiconductor Radiation Detectors

TOPIC: INNOVATIVE FOSSIL SOLIDS AND LIQUIDS PROCESSING AND RELATED CROSSCUTTING APPLICATIONS

Advanced Fuel Research, Inc. 87 Church Street P.O. Box 380379 East Hartford, CT 06138-0379	Adaptive Control of Nitrogen Oxide Reduction Processes
Cambridge Hydrodynamics, Inc. P.O. Box 1403 Princeton, NJ 08542	A Molecular Dynamic Aided Advanced Diagnostic Tool for Granular Flows
CeraMem Corporation 12 Clematis Avenue Waltham, MA 02154	Gas Separation Membranes Based on Permselective Films of Buckminsterfullerenes
CQ, Inc. P.O. Box 208 One Quality Center Homer City, PA 15748	Improving the Performance of Conventional and Column Froth Flotation Cells
Energy and Environmental Research Corporation 18 Mason Irvine, CA 92718	Selective Comminution of Coal for Enhanced Removal of Mineral Matter
ERC, Inc. 205 Research Park Drive P.O. Box 417 Tullahoma, TN 37388	An Optical Gas Temperature Probe for High Temperature Fossil Fuel Process Streams
EXPORTech Company, Inc. P.O. Box 588 New Kensington, PA 15068-0588	Pulverizer Modification for Pyrite Separation at the Power Plant

Grand Forks Activation Technologies 120 North Washington Street Grand Forks, ND 58203-3451	Fluid Bed Combustor Compliance Coal Production
Johanson and Associates Angwen Avenue, Route 7 Box 7336 Manchester, TN 37355	A Low Nitrogen Oxide High Performance Power Systems (HIPPS) Coal/Gas Burner
Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706	Low Cost Synthesis of Nanocrystalline Silicon Carbide Starting with Fullerene Precursors
Mountain States R&D International, Inc., and Arentzen Associates, Joint Venture P.O. Box 310 Vail, AZ 85641	Energy Reduction in Ball Mill Grinding
PSI PowerServe 20 New England Business Center Andover, MA 01810-1077	Flame Monitoring and Optimization of Coal-Fired Burners Based on Frequency Spectra Analysis
PSI Technology Company 20 New England Business Center Andover, MA 01810-1077	Development of an Innovative, Low Cost, Continuous Process for the Production of Nanoscale Silicon Carbide
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	Fullerene Based Catalysts for Heavy Oil Upgrading
Tri-Valley Research 3590 Churchill Court Pleasanton, CA 94588	A Coal On-Line Process Control Analyzer

TOPIC: ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY FOR FOSSIL ENERGY

ADA Technologies, Inc. 304 Inverness Way South Suite 110 Englewood, CO 80112	Controlling Mercury and Selenium Emissions from Coal-Fired Combustors Using a Novel Regenerable Natural Product

8

Advanced Fuel Research and On-Line Technologies, Inc. 87 Church Street P.O. Box 380379 East Hartford, CT 06138-0379	Improved Hot Stream Cleanup Using an In-Situ Multi-Gas Monitor
Aerometrics, Inc. 550 Del Rey Avenue Sunnyvale, CA 94086	An Optical Technique for Non-Intrusive Characterization of Fine Particulates in Flue Gas Streams
Blasch Precision Ceramics 99 Cordell Road Schenectady, NY 12304	A Ceramic Material and Process for Use in Monolithic Ceramic Cross-Flow Filters
Brooks Rand, Ltd. 3950 Sixth Avenue, Northwest Seattle, WA 98107	A Mercury Compound Luminescence Determination Method and Apparatus
Charles Evans and Associates 301 Chesapeake Drive Redwood City, CA 94063	An In-Situ Microanalysis of Coal Flyash: The Feasibility of Correlating Organic Surface Chemistry and Particle Composition
Chemat Technology, Inc. 19365 Business Center Drive Suite 8 Northridge, CA 91324	Coal Ash Tiles by Microwave Processing
Eltron Research, Inc. 2830 Wilderness Place #E Boulder, CO 80301	Electrolytic Polymer Cells for Carbon Dioxide Conversion
Environmental Elements Corporation 3700 Koppers Street P.O. Box 1318 Baltimore, MD 21203	Laminar Flow Electrostatic Precipitation
Environmental Elements Corporation 3700 Koppers Street P.O. Box 1318 Baltimore, MD 21203	Flue Gas Cleanup Using a Novel Corona Generator

Industrial Filter and Pump Manufacturing Company, Inc. 5900 Ogden Avenue Cicero, IL 60650	Simultaneous Hot Desulfurization and Improved Filtration in Coal Utilization Processes
M. L. Energia, Inc. P. O. Box 1468 Princeton, NJ 08542-1468	Optical Diagnostic Instrumentation for Use in Hot Gas Streams
Praxis Engineers, Inc. 852 North Hillview Drive Milpitas, CA 95035	Development of Expansive Cements Using Dry Flue Gas Desulfurization Solid Wastes
PSI PowerServe 20 New England Business Center Andover, MA 01810-1077	Toxic Materials Partitioning During Pulverized Coal Combustion: Measurement and Production
Reaction Engineering International 77 West 200 South, Suite 210 Salt Lake City, UT 84101	A Low Cost Method for Reducing Mercury Emissions in Fossil-Fuel Fired Power Plants
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143	Ultrasensitive In-Situ Detection of Toxic Flue Emission
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	Development of an Electrochemical System for Carbon Dioxide Concentration

TOPIC: ADVANCED TECHNOLOGY FOR THE RECOVERY, STORAGE, AND UTILIZATION OF NATURAL GAS

Acrion Technologies, Inc. 9099 Bank Street Cleveland, OH 44125	Landfill Gas Conversion to a Contaminant-Free Methane-Carbon Dioxide Reformer Feedstock for Methanol Synthesis
Alabama Cryogenic Engineering, Inc. P.O. Box 2470 Huntsville, AL 35804	Metal Monoliths for Conversion of Natural Gas to Liquid Fuel
Eltron Research, Inc. 2830 Wilderness Place #E Boulder, CO 80301	Tubular Catalytic Membrane Reactors for the Spontaneous Conversion of Humidified Natural Gas to Synthesis Gas

Eltron Research, Inc. 2830 Wilderness Place #E Boulder, CO 80301	A Membrane Reactor for the Spontaneous Conversion of Natural Gas and Carbon Dioxide Mixtures into Valuable Feedstock
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06813	A Multi-Functional Component to Simplify Fuel Cell Power Plants
Goldrus Producing Company 1 Post Oak Circle Houston, TX 77024-7001	Treatment and Disposal of Naturally Occurring Radioactive Materials in Natural Gas Drilling, Production, and Processing
J Integral Engineering 165 Southwest Tualatin Loop West Linn, OR 97068	Cost Effective Stimulation of Shallow Gas Wells Using High Energy Gas Fracturing Fielded Without a Wireline or Workover Rig
Kalsi Engineering, Inc. 745 Park Two Drive Sugar Land, TX 77478	Development of a Higher Pressure Rotary Blowout Preventer for Safe Directional Drilling in Underbalanced Applications
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025	Membrane Module Development for a Natural Gas Dehydration Process
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025	Separation of Nitrogen from Natural Gas Using Novel Membranes and Membrane Processes
Northwest Fuel Development, Inc. 4064 Orchard Drive Lake Oswego, OR 97035	Continuous Pressure Swing Adsorption (CPSA) for Nitrogen Rejection from Natural Gas
NW Resources P.O. Box 187 Socorro, NM 87801	Forecasting Reservoir Thickness with Fractals

Process Technology, Inc. 14811 St. Mary's Lane Suite 165 Houston, TX 77079	Redesign of Ammonia Absorption Refrigeration Units for Low Temperature Applications in Natural Gas Processing
Sage Discovery, Inc. 345 Market Street P.O. Box 882 Meeker, CO 81641-0882	Systematic Mapping of Natural Fractures to Predict Coalbed Methane Production
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143	Sulfur Recovery from Hydrogen Sulfide-Prone Natural Gas
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143	Removal of Hydrogen Sulfide from Natural Gas by Electron Beam Irradiation

TOPIC: COAL-BASED POWER SYSTEMS TECHNOLOGY

Busek Company, Inc. 19 Kearney Road Needham, MA 02194	High Temperature Brazing of Silicon Carbide
Selee Corporation 700 Shepherd Street Hendersonville, NC 28792	A Highly Efficient Two Stage Ceramic Foam Burner for Clean Combustion of Low BTU Coal Gas
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	A Long Life Zinc-Oxide-Titanium-Oxide Sorbent

TOPIC: ENHANCED OIL RECOVERY

Drilling Measurements, Inc. 118 Thruway Park Broussard, LA 70518	An Economical Borehole Compensated Chlorine/Improved Porosity Logging Tool
Optiphase, Inc. 7652 Haskell Avenue Van Nuys, CA 91406-2005	A High Performance Wellbore Logging Tool Using Fiber Optic Gyro Technology

Terra Tek, Inc. 420 Wakara Way Salt Lake City, UT 84108	A Practical High Resolution Petrographic Imaging System for Assessing Reservoir Quality

TOPIC: ROBOTS FOR NUCLEAR ENVIRONMENTS

Reveo, Inc. 8 Skyline Drive Hawthorne, NY 10532	Interface Designs for Telepresence and Remote Sensing Systems Using Non-Immersive Virtual Reality
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International Space Enterprises 4909 Murphy Canyon Road San Diego, CA 92123	Nuclear Power Feasibility for Near Term Commercial Applications on the Lunar Surface
Thermacore, Inc. 780 Eden Road Lancaster, PA 17601	A Reduced-Mass Ground Testable Radiator Using High-Temperature Loop Pipes
Thermacore, Inc. 780 Eden Road Lancaster, PA 17601	Hydrogen Permeation Barriers for Bimodal Reactors

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EMEC Consultants 4221 Roundtop Road Export, PA 15632	Oxygen-Evolving Anodes for the Electrolysis of Calcium Oxide

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Curriculum Television Corporation 2382 Faraday Avenue Suite 300 Carlsbad, CA 92008	KIDVID - Mathematics Games by Kids for Kids
Gautier-Downes and Associates 2656 Montrose Place Santa Barbara, CA 93105	Development of a Computer Game Prototype to Teach Physical Geography
Research Development Corporation 2875 Towerview Road Suite A4 Herndon, VA 22071	An Intelligent Tutoring Game to Teach Scientific Reasoning

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Goremotive Industries, Inc. 20944 Sherman Way Suite 206 Canoga Park, CA 91303	Advanced Catalysts for Ultra-Low Emission Control in Natural Gas Fueled Vehicles
JX Crystals 4617 174th Place, Southeast Issaquah, WA 98027	A Clean and Efficient Thermophotovoltaic Generator for Electric Vehicles
Maxdem, Inc. 140 East Arrow Highway San Dimas, CA 91773	Molecular Composite Plastics for Lightweight Green Cars
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025	A Membrane Reactor for the Production of Hydrogen Fuel from Hydrocarbon Liquids
UES, Inc. 4401 Dayton-Xenia Road Dayton, OH 45432-1894	Surface Hardening of Polymeric Composites by High Energy Ion Irradiation
Visual Computing Systems Corporation 9540 Highway 150 Box 250 Greenville, IN 47124	An Energy Efficient Electric Vehicle

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Quantum Group, Inc. 11211 Sorrento Valley Road San Diego, CA 92121	Thermophotovoltaic Generator Efficiency Improvement
Selee Corporation 700 Shepherd Street Hendersonville, NC 28792	A Novel High Strength Ceria-Zirconia Toughened Alumina Ceramic with Superior High Temperature Corrosion and Erosion Resistance
Space Power, Inc. 621 River Oaks Parkway San Jose, CA 95134	Design and Applications of Close-Spaced Thermionic Converters with Novel Isothermal Electrodes
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	Rare Earth Endohedral Fullerenes as New Nonlinear Optical Materials
Thermal Electric Devices, Inc. 1009 Bradbury Drive, Southeast Albuquerque, NM 87106	Development of Metal Hydride Materials for High Coefficient of Performance Heat Pumps

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Containerless Research, Inc. 910 University Place Evanston, IL 60201-3149	An Apparatus for Structural Analysis of High Temperature Materials Using Synchrotron Radiation
Radiation Monitoring Devices, Inc. 44 Hunt Street Watertown, MA 02172	A Novel Detector for Neutron Diffraction Studies
X-Ray Analytics, Ltd. Box 678 Upton, NY 11973	An Analytical Research Materials Characterization Facility Based on Synchrotron Radiation

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Bend Research, Inc. 64550 Research Road Bend, OR 97701-8599	High-Performance Membranes for Gas, Vapor, and Liquid Separations
BSI Corporation 9924 West Seventy Fourth Street Eden Prairie, MN 55344	Photoaffinity Immobilization of Fusion Proteins on Biosensor Surfaces
CeraMem Corporation 12 Clematis Avenue Waltham, MA 02154	Organic-Inorganic Composite Membranes for Gas Separation and Vapor Permeation
Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706	Electrode Materials for Rechargeable Lithium Batteries

Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025	Novel High Performance Glassy Polymer Composite Membranes for Gas Separation
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Third Wave Technologies, Inc. 2800 South Fish Hatchery Road Madison, WI 53711-5399	Signal Amplification for Specific Nucleic Acid Detection

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DOE/ER-0630

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE I AWARDS

1994

U.S. Department of Energy
Office of Energy Research
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PREFACE

The SBIR program enables DOE to obtain effective, innovative solutions to important problems through the private sector, which has a commercial incentive to pursue the resulting technology and bring it to the marketplace. The growing number of awardees, many of them started in business in response to SBIR solicitations, is becoming a significant resource for the solution of high risk, high technology problems for the Department. As detailed below, this publication describes the technical efforts for SBIR Phase I awards in 1994. It is intended for the educated layman, and may be of particular interest to potential investors who wish to get in on the ground floor of exciting opportunities.

The Federal SBIR Program

This program, now completing its twelfth year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Eleven Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over $100 million. The agencies were required to set aside 1.5% of those budgets in Fiscal Year (FY) 1994 to fund SBIR projects. (This amounted to about $53 million in FY 1994 for the Department of Energy.) Each agency solicits proposals from small science- and technology-based US firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to $75,000 in FY 1993. Phase II is the principal research or R&D effort, and the awards were as high as $600,000 in FY 1994 for work to be performed in a period of up to two years. Phase III is the commercial application of the research or R&D effort by the small businesses using non-Federal funding or, alternatively, it may involve follow-on non-SBIR Federal contracts for products or services desired by the Government. The program continues to strengthen the role that small, innovative firms play in meeting the Nation's research and development needs and in commercialization of ideas developed through federally funded R&D.

Phase I Awards for FY 1994

Contained in this booklet are abstracts of the Phase I awards made in FY 1994 under the DOE SBIR program. The 212 Phase I projects described here were selected in a highly competitive process from a total of 2,276 grant applications received in response to the 1994 DOE annual SBIR Solicitation. The selections for awards were made on scientific and technical merit, as judged against the specific criteria listed in the Solicitation. Conclusions were reached on the basis of detailed reports returned by reviewers drawn from DOE laboratories, universities, private industry, and government. (Any discrepancies noted in prior DOE releases naming the firms selected for awards are due either to the firm changing its name after the award selection or to the firm not proceeding to a signed grant.) It is expected that between one-third and one-half of the Phase I projects will be continued into Phase II.

The work described in the abstracts is novel, high-risk research, but the benefits will also be potentially high if the objectives are met. Brief comments on the potential applications, as described by the awardee, are given after each abstract. Individuals and organizations, including venture capital and larger industrial firms, with an interest in the research described in any of the abstracts are encouraged to contact the appropriate small business directly.

The DOE SBIR Program

DOE's FY 1994 annual Solicitation contained 43 technical topics in the areas of basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, energy efficiency and renewable energy, fossil energy, nuclear energy, environmental management, nonproliferation and national security, and environment, safety, and health. There is keen competition because awards are made solely on the basis of scientific and technical merit, regardless of the technical topic.

As a measure of the program's success, eleven DOE SBIR projects have received R&D-100 Awards from Research and Development Magazine, which selects the 100 most significant technical products each year. In addition, five DOE awardees were chosen among the 500 fastest-growing American private companies, in the December 1991 issue of Inc. Magazine, based on their growth in sales. Also, from the first six cycles of awards (Phase II projects completed between 1986 and 1991), DOE SBIR winners have already received approximately $260 million in Phase III funding, which is about 60% larger than the SBIR support they were given. This number is expected to grow significantly in the next few years.

The DOE SBIR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. In the first year of Phase II awards (1984), a system was devised and implemented that allowed Phase I awardees who felt they were ready to submit their Phase II applications before their Phase I grants ended, to do so. For each of the eleven years in which Phase II awards have been made, such grantees who were chosen for Phase II funding were able to begin their projects without an interruption in funding. Since 1984, about 40 per cent of the Phase II awardees have had continuous funding between Phases I and II.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, DOE has instituted a special training project, supported by non-SBIR funds. For the past five years, successful Phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participation in the 1991 project, the SBIR companies have already received more than $14 million for commercialization of their SBIR research, with a projected royalty stream from option agreements of an additional $24 million over the next three to five years. About 43% of the firms that completed the project have received further funding for their work. Sources of capital that wish to consider participation in future programs should contact Dr. Robert Berger, U.S. Department of Energy SBIR Program, ER-16, Washington, D.C. 20585, (telephone 301-903-3054).

Samuel J. Barish
SBIR Program Manager
US Department of Energy
Washington, DC 20585

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Radiation Monitoring Devices, Inc., Watertown, MA 112

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209. Radiation-Hard and Solar Blind Ultraviolet X-Ray Chemically Vapor Deposited-Diamond Photodiode Detectors
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ENGINEERING ADVANCES FOR PHOTOVOLTAIC SYSTEMS

1

A Trimode Power Processor to Optimize Photovoltaic, Battery, and Diesel-Generator Sources for Economic Stand-Alone Power Plants--Abacus Controls, Inc., 80 Readington Road, Somerville, NJ 08876; (908) 526-6010
Mr. George O'Sullivan, Principal Investigator
Mr. George O'Sullivan, Business Official
DOE Grant No. DE-FG05-94ER81689
Amount: $71,673

A hybrid power plant, consisting of a diesel generator, a battery for energy storage, a photovoltaic array or other renewable energy source, and an inverter/battery charger, will be economically feasible in the near future both within the United States and throughout the developing world where rural areas are starving for quality power. At present diesel generators run continuously; the new hybrid power plants will transfer power sources between the diesel generator and the inverter at least daily. The planned Phase I research methodically approaches the control of the inverter so that the transfer of power is a smooth process. An adaptive controller for the inverter/battery charger will measure and store the characteristics of a diesel generator in the field and adjust the transfer of power by operating the inverter in parallel with the diesel generator for a few seconds at each power transfer. The success of Phase I will be demonstrated with computer simulations that predict proper operation both in the steady state and during all power transfers.

Anticipated Results/Potential Commercial Applications as described by the awardee: The unit under investigation will provide a low cost solution for the field installation of hybrid power plants. In Phase II, a family of products spanning the power range from 50 to 250 kW will be available for prototype and small production runs. In Phase III, under company sponsorship, production tooling and value engineering will be added to the hybrid power plant to generate marketplace attractions in technology and price.

2

High Speed Sheet Growth of Thin Silicon Films--AstroPower, Inc., Solar Park, Newark, DE 19716; (302) 366-0400
Mr. Jeffrey E. Cotter, Principal Investigator
Mr. Thomas J. Stiner, Business Official
DOE Grant No. DE-FG05-94ER81713
Amount: $75,000

A novel silicon deposition process capable of depositing high quality thin-film silicon layers on low cost supporting substrates will be investigated in Phase I. The substrate will include a reflector for light trapping. The planned deposition process will allow the formation of silicon layers 20 to 30 microns thick, optimizing the performance of crystalline silicon as a solar cell material. This new method of depositing thin silicon layers is based on an extension of existing well developed metallurgical processes. The objective of this project will be to develop the deposition process to produce 20 to 30 micron thick layers of silicon continuously. The advantages of such a process will include (1) high deposition rates (up to 100 times higher than conventional chemical vapor deposition), (2) continuous production, (3) high purity, and (4) low cost. As-deposited films will be evaluated for efficiency potential.

Anticipated Results/Potential Commercial Applications as described by the awardee: The commercial market for photovoltaics is presently limited by the cost of single crystal silicon solar cells. The planned work will advance the alternative, low cost solar cell by reducing the thickness and increasing the generation rate per unit area of the present polycrystalline silicon technology. A low-cost solar cell will have a wide market base in utility-scale photovoltaic power generation, as well as a smaller market for remote power applications.

3

Low Cost, High Purity Silicon by Alkaline Glycolic Digestion of Silica--AstroPower, Inc., Solar Park, Newark, DE 19716; (302) 366-0400
Mr. James B. McNeely, Principal Investigator
Mr. Thomas J. Stiner, Business Official
DOE Grant No. DE-FG05-94ER81712
Amount: $75,000

The solar cell application of crystalline silicon thin-film photovoltaic (PV) technologies is currently limited by the high cost of the silicon raw material. This is a result of the carbothermal reduction metallurgical process used to create the semiconductor-grade silicon from silica. There is a novel alternative organosilicon chemistry, based on alkaline glycolic digestion of silica, that does not involve the energy-intensive, costly carbothermal reduction. The Phase I project investigates the feasibility of this chemistry to create a high purity silicon raw material by identifying appropriate nucleophiles to effect a one- or two-step reduction of the glycolic digestion product, and by identifying purification operations on precursor intermediates. This phase concludes with a feasibility and economics study for a pilot-plant facility. The cost of silicon solar photovoltaic cells is largely affected by the cost of the silicon raw material. If the silicon raw material can be reduced from its current level of $10 to $15 per kilogram (based on scrap silicon fall-out from the electronics industry) to $1 to $2 per kilogram, a $3 per peak watt solar cell would accordingly drop in cost to less than $1 per peak watt. As the crystalline silicon solar cell industry grows into the 10's of megawatts, the demand will exceed the supply available from the electronics industry, and the price for the silicon raw material will increase substantially. Furthermore, as the PV industry reaches 1 gigawatt by the year 2000, it will not be able to obtain pure silicon fall-out from the electronics industry, whose total use of silicon raw material was equivalent to only 120 megawatts in 1992. This new and innovative supply of low-cost, high-quality silicon can meet the growth and demand of the crystalline silicon solar cell industry.

Anticipated Results/Potential Commercial Applications as described by the awardee: The high purity silicon material produced by the successful implementation of this process at a lower cost and at a quality that is equivalent to semiconductor-grade silicon, could be available immediately to reduce significantly the cost of silicon semiconductor devices and crystalline silicon solar cells. This program could contribute significantly to attaining sunlight generated electricity at 5 to 6 cents per kWh and can remove the major silicon raw material obstacle to reaching 1 gigawatt capacity by the year 2000.

4

A Resonant Converter for Photovoltaic Systems--Electronic Power Conditioning, Inc., 1895 Northwest Ninth Street, Suite A, Corvallis, OR 97330; (503) 753-7220
Dr. Hian K. Lauw, Principal Investigator
Mr. Dallas A. Marckx, Business Official
DOE Grant No. DE-FG03-94ER81746
Amount: $74,725

All photovoltaic (PV) systems require power electronics to convert variable voltage DC from the PV panels to usable, regulated power with high quality. At high ratings, AC is generally required. Conventional converters have several problems, including high cost, excessive harmonics, excessive losses, safety issues, poor power factor, vulnerability of the power switches, audible noise, and electromagnetic interference (EMI) in violation of FCC standards. An innovative resonant converter known as the unipolar series resonant converter (USRC) will make significant improvements in each area. The USRC uses thyristors with zero voltage and current switching, minimizing losses and cost. It produces sinusoidal voltage within IEEE 519 standards, eliminating filters and associated energy losses and cost. The USRC can step up voltage without a transformer. Versions of the USRC are operating, but adaptation to PV applications is required. This project will develop a four-wire version with a grounded neutral leg that permits the grounding of both the PV system and load without isolation transformers. In Phase I, a 3 kw version will be assembled and tested in the laboratory. In addition, the cost and performance of a 100 kw module will be projected. In Phase II, the 100 kw module could be demonstrated in the field. The 100 kw module could be installed in parallel with other similar modules in both grid-connected and standalone PV systems. The wide conversion functionality of the USRC technology makes it a likely candidate for hybrid energy systems. A cost of less than $100/kw is attainable for the system.

Anticipated Results/Potential Commercial Applications as described by the awardee: The result will be proof of feasibility in terms of cost and performance of the proposed resonant converter. Given its higher efficiency, low cost, and other favorable characteristics, the 100 kw module might become the converter of choice for most PV systems between 10 kw and 500 kw. Other applications include adjustable-speed drives, uninterruptible power supplies, variable-speed generation systems using wind and engine prime movers, battery chargers, and frequency changers.

5

A Photovoltaic Wire Grid Design and Process--
Energy Conversion Devices, Inc., 1675 West Maple Road, Troy, MI 48084; (810) 280-1900
Mr. Timothy J. Bernard, Principal Investigator
Mrs. Nancy M. Bacon, Business Official
DOE Grant No. DE-FG02-94ER81754
Amount: $75,000

The current manufacturing and pilot operations utilize module assembly processes that have relatively high labor and material costs. This project addresses the cost and performance issues of processing the grids and bus bars used in amorphous silicon alloy thin film photovoltaic modules. Specifically, Phase I will address the problems of the silver paste-based current collection grid system, which compromises the reliability and adds to the cost of the amorphous silicon photovoltaic modules. Thin solid copper wires will be used as a combined grid/bus bar system wherein the wires serve the dual purpose of collecting the current from the top conductor as well as carrying it away from the active area of the cell. This new gridding process will result in cheaper photovoltaic modules that use significantly less expensive materials and have increased efficiencies regardless of the size of the module. The modules will also have improved electrical isolation as a result of the new grid system. Overall, this process improvement will enhance the performance of existing module manufacturing and pilot facilities, and increase the reliability and decrease the cost per peak watt of its modules.

Anticipated Results/Potential Commercial Applications as described by the awardee: Higher collection efficiency, lower manufacturing costs, and improved electrical isolation and reliability of photovoltaic modules over present current collection grids should be realized. This would advance photovoltaic product, process, and manufacturing technology, reduce the cost of modules and expand commercial market applications, all of which will benefit the U.S. in creation of jobs, industrial growth, and a cleaner environment, while contributing to national security by reducing the need for importation of oil.

6

Monolithic Integration of Thin Film Photovoltaics on Insulated Metal Substrates--
Energy Photovoltaics, Inc., 276 Bakers Basin Road, Lawrenceville, NJ 08648; (609) 587-3000
Dr. Alan E. Delahoy, Principal Investigator
Mr. David A. Jackson, Business Official
DOE Grant No. DE-FG05-94ER81755
Amount: $74,924

Thin film semiconductors offer the best opportunity for cost reduction of photovoltaics. Glass is commonly used as a substrate, but breakage remains a problem. This Phase I project will demonstrate the technical feasibility of preparing monolithically integrated, thin film photovoltaic (PV) cells on insulated metal substrates. The key requirement is development of a low cost metal/insulator combination that is compatible with the PV technology. The insulating layer must exhibit good adhesion and be free of pinholes. Anodized aluminum sheet and glass-coated (porcelainized) steel have been identified as promising choices. Insulated substrates will be prepared by low temperature anodization of aluminum (Al) under appropriate conditions to form thick oxides (which will then be sealed), and by formulation of alkali aluminoborosilicate glass frits followed by bonding to low carbon steel sheet at 850°C. The coatings will be tested for adequate dielectric properties, breakdown voltage in excess of 1500 V, and ion motion. Alkali-free frits will also be evaluated. Thin film, monolithically interconnected structures will be fabricated in the configurations copper indium selenide (CIS) on porcelainized steel and amorphous silicon on anodized Al. During CIS formation, the substrate will be exposed to selenium and to temperatures up to 550°C. The resulting devices will be analyzed by a variety of techniques for integrity of the insulator, adhesion, impurities, deleterious chemical reactions, and solar conversion efficiency. The above operations will be iterated and optimized with the goal of forming working prototype devices.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful development of sheet-metal based, monolithically interconnected, thin film photovoltaics would allow the large scale manufacture of building-integrated PV products such as roofing materials, sidings, and facades, and PV shells for electric vehicles. These multi-functional products are installed to perform conventional functions such as weather protection, but additionally generate electricity. The economic barrier to PV use is thereby reduced.

7

A Novel Interconnect Scheme for Photovoltaic Modules--Evergreen Solar Company, 107 York Terrace, Brookline, MA 02146; (617) 625-5322
Dr. Jack I. Hanoka, Principal Investigator
Mr. Richard G. Chleboski, Business Official
DOE Grant No. DE-FG02-94ER81763
Amount: $75,000

A novel approach to the interconnection of photovoltaic cells is proposed. It utilizes cutting-edge technologies from the hybrid circuit, ceramics, and polymer fields adapted for photovoltaic processing. The entire concept has been made possible as a result of recent advances in state-of-the-art solar cell processing. This new interconnect method contacts only the rear face of the solar cell and is solder-free. This means that it lends itself to virtually continuous, high speed, low cost manufacturing, and in addition, avoids any environmental issues connected with the use of solder. Given the somewhat unique solar cell configuration, the key technical issues to be addressed in Phase I are the reduction of the metallization fingers' series resistance and maintenance of a high shunt resistance between the front and rear contacts. A detailed survey of commercially available materials in the areas of thick film pastes and high dielectric strength, low cost polymer sheet materials will be a part of this study.

Anticipated Results/Potential Commercial Applications as described by the awardee: At present, module manufacturing, of which interconnection is a significant portion, represents approximately half the cost of producing a photovoltaic panel. Because of its simplicity and high throughput capabilities, this process has the potential to significantly reduce labor, material, utility, and capital costs. Combined, these would result in an overall reduction in interconnection costs of 80%. When successfully deployed, this will be an important contribution toward the goal of economic generation of electricity from sunlight.

8

An Innovative Approach for Large Area Photovoltaic Material Processing--International Solar Electric Technology, Inc., 8635 Aviation Boulevard, Inglewood, CA 90301; (310) 216-4427
Dr. Bulent Basol, Principal Investigator
Dr. Bulent Basol, Business Official
DOE Grant No. DE-FG03-94ER81789
Amount: $74,940

Semiconductors of copper indium diselenide and related compounds are important solar cell materials. Devices with over 15% solar-to-electric conversion efficiency have already been demonstrated on the polycrystalline thin films of these materials in the laboratory. The aim of this Phase I project is to develop new and innovative processing approaches that can be scaled up for the production of large area, high efficiency, photovoltaic modules. The approach involves reaction of indium-rich and copper-rich precursors to form a copper indium selenide film with the right composition and microstructure that can eventually be used to fabricate photovoltaic modules with efficiencies greater than 15%. The specific processing steps necessary for high efficiency solar cell fabrication will be determined, and plans made for the adaptation of these steps to a large area sputtering facility. Actual large area depositions would be carried out in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: If this research effort is successful, an industrial process that can produce high efficiency, large area thin film photovoltaic (PV) modules will be developed in Phase II. Thin film PV products have many terrestrial and space power generation applications. The largest market for PV is the utility power generation market which requires a high efficiency product at low cost. Thin film PV technologies could respond to this need.

9

A 50 Watt DC-AC Inverter for Stand-Alone and Grid-Connected Photovoltaic Applications--Solar Design Associates, P.O. Box 242, Harvard, MA 01451-0242; (508) 456-6855
Dr. Robert H. Wills, Principal Investigator
Mr. Steven J. Strong, Business Official
DOE Grant No. DE-FG02-94ER81862
Amount: $75,000

For both utility-intertied and stand-alone photovoltaic (PV) systems, the DC wiring and its associated issues is always, except for the smallest of systems, a major problem. AC power transmission techniques will be used to completely eliminate DC interconnection. This will be done by incorporating a small DC-AC inverter on the back of each PV module so that the module output is standard 120 Volts, 60 Hz, AC current. AC power transmission can be used for both utility-interactive and stand-alone systems. A major advantage of these systems is compatibility - the 120 V AC bus provides a common ground for all components to interconnect. The benefits of maximum power point tracking on an individual module basis, the elimination of DC wiring, custom string combiners, blocking diodes, series string losses and the standardization offered by a common 120V AC bus voltage can outweigh the additional cost of the inverter. In Phase I of the effort, a proof-of-concept 50 Watt DC to AC inverter that is designed to mount on the back of a photovoltaic module will be developed. It will deliver 120 Volt 60 Hz AC power to the utility grid or to a local stand-alone grid. Appropriate manufacturing techniques (e.g. Application-Specific Integrated Circuits, hybrid circuits, monolithic and "smart power" approaches) will be examined, estimates of inverter size and the cost and efficiency for various scales of production will be prepared, and the feasibility of incorporating storage elements with the inverter on the back of the PV module to make truly modular stand-alone PV power systems will be studied.

Anticipated Results/Potential Commercial Applications as described by the awardee: This device could bring photovoltaics to the "appliance level", both for utility-interactive and for larger-scale stand-alone systems. In fact, this concept blurs the boundary between the two, as stand-alone systems effectively gain their own mini-AC grid. The main commercial market should be utility-interactive power systems, followed by support of diesel power grids in remote areas, with smaller stand-alone systems still being a significant market. The emergency power/disaster relief market could also be well served by this product.

10

Low Cost Solar Cell Leads for Use in Photovoltaic Modules--Solar Engineering Applications Corporation, P.O. Box 62246, Sunnyvale, CA 94088; (408) 986-9231
Mr. Neil Kaminar, Principal Investigator
Mr. Neil Kaminar, Business Official
DOE Grant No. DE-FG03-94ER81863
Amount: $75,000

The copper/solder/metallization/silicon layers used to bond electrical leads to solar cells have vastly different thermal expansion rates. This causes severe stresses when continuous solder joints are used. This problem has been solved with a special lead design that uses a multitude of fingers soldered to the cells. The purpose of this project is to develop a more cost-effective lead/cell design. Two technical approaches will be investigated, to be used singularly or together. The first approach is to add a strain relief feature to a continuous lead. The second approach is to add a solder resist pattern so that continuous leads are only bonded to the cell in spots. Finite element stress analysis will be used in Phase I to investigate different designs, and proof-of-concept samples of the most promising candidates will be manufactured and subjected to environmental testing. Phase II will introduce the most successful design into the production line.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project could have far reaching applications in the photovoltaic industry. If successful, the technique can be applied to other concentrators and to one-sun modules. Given modest volume, the introduction of a more cost-effective lead/cell design, and other planned improvements, could enable the grid to be sold for under $1.10 per installed AC Watt.

11

Very Low-Cost/High-Efficiency Thin-Film Silicon Photovoltaic Technology--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Anton C. Greenwald, Principal Investigator
Mr. Patrick N. McDonnell, Business Official
DOE Grant No. DE-FG02-94ER81867
Amount: $74,992

The goal of this project is to achieve a cost reduction on the order of 50% in thin-film photovoltaic (PV) technology by developing a high-efficiency chemical vapor deposition (CVD) silicon cell utilizing a low-cost substrate. In Phase I a surface relief structure will be formed on a glass substrate by making a negative replica of a reusable texture-etched silicon surface. A thin silicon film will be deposited on this textured substrate by CVD from silane and then recrystallized by rapid thermal annealing. The artificial surface relief will induce a preferred orientation of the regrown crystallites (graphoepitaxy) so that the film has a nearly single crystal, or at least large-grained (≥ 1 mm), structure. In Phase II, a cell structure with all contacts on the back surface will be fabricated, the textured glass substrate becoming the light-trapping front cover of the cell. Although highly innovative, this approach is at an acceptably low level of risk because it is based upon the synthesis of five previously demonstrated technologies: graphoepitaxy, scanned recrystallization, interdigitated back contact cell structures, light trapping, and high lifetime CVD silicon.

Anticipated Results / Potential Commercial Applications as described by the awardee: The capability of depositing high quality, thin-film silicon cell structures directly from a source gas onto low cost substrates will obviate the long-standing economic barriers to large scale PV power generation. Its impact upon the commercial, environmental, and strategic well-being of the Nation has been stated repeatedly and in great detail by the various Federal PV initiatives.

12

Development of a Low Cost High Concentration Photovoltaic Dense Array Module for Use with Reflective Concentrators--SunPower Corporation, 435 Indio Way, Sunnyvale, CA 94086; (408) 991-0900
Dr. Pierre Verlinden, Principal Investigator
Dr. Richard Swanson, Business Official
DOE Grant No. DE-FG03-94ER81872
Amount: $74,314

A one kilowatt test-bed photovoltaic reflective dish system with 13.6 percent overall efficiency has been demonstrated. The dish was operated for two months, at which time one of the receiver modules developed a crack in its substrate and began leaking coolant. Phase I will design and fabricate a second-generation dense-array module and test it on a one kilowatt test-bed concentrator. The new module will use an alumina substrate, rather than the silicon substrate of the first-generation design, along with a new substrate-to-module-housing seal based on o-rings, rather than the adhesives of the first-generation design. The same innovative, integral heat exchanger will be employed. The module will be subjected to qualification testing and operated for an extended period to demonstrate reliability. By incorporating new 26 percent efficient cells into a new dense-array module design, it is hoped to demonstrate the feasibility of high-performance, reliable, cost-effective photovoltaic dish systems with an overall efficiency of over 16 percent.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful demonstration of a cost-effective, high-concentration dense-array module is the remaining technical hurdle for commercialization of reflective photovoltaic concentrator systems. The primary early application of reflective-dish photovoltaic systems will be for distributed-generation grid support in areas with high air conditioning peak loads, and for remote photovoltaic diesel hybrid power systems for military bases, resorts, and islands currently operating on diesel generators.

FUEL CELLS FOR TRANSPORTATION

13

Improved Activated Carbon for Hydrogen Storage--Arcanum Corporation, P.O. Box 1482, Ann Arbor, MI 48106; (313) 665-4421
Mr. John A. Getsoian, Principal Investigator
Mr. Helmut F. Stern, Business Official
DOE Grant No. DE-FG02-94ER81710
Amount: $73,821

Amoco process activated carbons have been found to have high storage capacity for alternate fuel vehicle energy sources such as hydrogen and methane. Nearly all of the gas these carbons can store is adsorbed in microporous regions where pore diameters are less than 40 Å. However, the micropores only account for somewhat more than half of the total pore volume in these materials. The balance of the pore volume comprises of large pores which do not store low molecular weight gases efficiently. Analysis of the process reaction chemistry and material balance indicate that novel modifications to the existing syntheseis technique may result in an activated carbon product with a much higher proportion of its total pore volume in the microporus range. Such a material should have substantially higher gas storage capacities than currently available materials and could provide substantial improvements in the cost and feasibility of hydrogen or methane fuel vehicles. Phase I will construct a suitable batch reaction system for the synthesis of Amoco carbon and execute a plan designed to test the effects of reductions in water feed to the reaction system and the effects of feed mesophase concentration on micropore yield. Additional dehydration of the caustic in the reactor will be attempted prior to feeding the carbon substrate. Testing will determine whether it is feasible to design equipment to the fairly narrow requirements of the reaction that will have enough evaporation capability to achieve significant additional concentration of 87% potassium hydroxide upstream of the carbon feed point.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result of this approach is a demonstration of the feasibility of producing activated carbon adsorbents with higher volumetric gas storage capacities. An attendant benefit of increased volumetric capacity yield will be a reduction in capital cost of production because the equipment for this process is sized for the bulk volume of the material going through it, while the value of the product inheres in the storage capacity within that volume. Thus the same equipment can produce more total volume storage capacity. Since commercial potential of this material is highly sensitive to its cost/performance ratio, the success of the proposed approach will increase the commercial viability of the product and of technologies such as hydrogen or methane fueled vehicles in which it may be used.

14

Non-Precious Metal Catalysts for Proton Exchange Membrane Fuel Cells by Ion Beam Synthesis--ElectroChem, Inc., 400 West Cummings Park, Woburn, MA 01801; (617) 932-3383
Mr. Calvin L. Bushnell, Principal Investigator
Dr. Radha Jalan, Business Official
DOE Grant No. DE-FG02-94ER81744
Amount: $75,000

One of the challenges facing the commercialization of proton exchange membrane (PEM) fuel cell technology involves the reduction of cost, specifically that of the electrocatalyst. The search continues for non-noble metal catalysts which are lower in cost and exhibit equivalent or better performance. PEM fuel cells for transportation power sources have additional benefits if they have a capability to operate efficiently on fuels derived from methanol. This requires that the anodes have a tolerance to impurities without poisoning the catalyst. In previous work carbon materials which were surface activated with nitrogen were found to have significant catalytic activity for phosphoric acid cathodes. Furthermore, transition metals were deposited on carbon supports as well. The procedure was based on ion implantation. This Phase I project will prepare both anode and cathode catalysts, evaluate them in PEM cells for their catalytic activity and their tolerance to contamination contained in methanol and methanol reformate, and compare them to platinum catalysts. Higher cathode catalytic activity will be accomplished by the use of an electron cyclotron resonance ion beam source to create higher charge state ions to increase the reaction rate in preparing the catalyst surface. Anode catalysts will be prepared by novel and proprietary methods to catalyze carbon supports with transition metals.

Anticipated Results/Potential Commercial Applications as described by the awardee: At the end of Phase I, the potential catalytic activity of anode and cathode catalysts prepared by ion-beam synthesis should have been demonstrated. If successful, this approach paves the way to fabricate low cost and impurity tolerant PEM fuel cells for use in transportation.

15

Contamination-Tolerant Anodes for Polymer Electrolyte Membrane Fuel Cells--ICET, Inc., 916 Pleasant Street, Unit 12, Norwood, MA 02062; (617) 769-6064
Dr. Shantha Sarangapani, Principal Investigator
Mr. Srinivasan Sarangapani, Business Official
DOE Grant No. DE-FG02-94ER81779
Amount: $75,000

Polymer Electrolyte Membrane (PEM) fuel cells have several advantages over conventional electrolyte fuel cells. Their high power densities make them prime candidates for electric vehicles, in conjunction with a methanol reformer. However, the impurities from the methanol reformate affect the performance of the platinum catalysts, causing reduction in power densities. This project aims to develop certain macrocyclic promoters for countering the poisoning effect of the adsorbed residues from the impurities present in the hydrogen stream. Several catalyst systems will be screened in half cells and selected catalysts will be tested in a PEM fuel cell. During Phase II these catalysts will be developed towards maximum power densities.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase I is expected to result in the identification of certain enhanced catalysts for use with reformate in PEM fuel cells. A good poison-resistant catalyst will make the cost of electric vehicle power sources affordable for consumer use.

16

Contamination-Tolerant Anodes for Proton Exchange Membrane Fuel Cells--Lynntech, Inc., 7610 Eastmark Drive, Suite 105, College Station, TX 77840; (409) 693-0017
Dr. Oliver J. Murphy, Principal Investigator
Dr. G. Duncan Hitchens, Business Official
DOE Grant No. DE-FG05-94ER81800
Amount: $75,000

There is a renewed interest in fuel cells as primary power sources for electric vehicles. The acidic proton exchange membrane fuel cell operates at a maximum temperature of 95°C and, at present, relies on the use of platinum-based electrocatalysts. For acid fuel cells operating at temperatures below 130°C, hydrogen is the most active common fuel that can be used. However, to be of practical use for power generation, a fuel cell must be capable of using an available fuel, such as methanol or natural gas. For transportation applications, it has been proposed that the hydrogen required for proton exchange membrane fuel cells will be produced by the steam reforming of methanol. However, the steam reforming of methanol results in the production of low levels of carbon monoxide. The presence of carbon monoxide and trace contaminants, such as formaldehyde, acetaldehyde, formic acid, and acetic acid in the hydrogen fuel gas stream severely degrades the performance of proton exchange membrane fuel cells, since carbon monoxide acts as a poison to platinum electrodes operating in the range of potentials, 0-0.5 V (normal hydrogen electrode), at temperatures less than 130°C in acidic electrolytes. In addition to selective catalytic oxidation of carbon monoxide in the reformer output, a number of other methods have been considered. An alternative approach to avoid the degradation in performance of proton exchange membrane fuel cells by carbon monoxide and other small organic molecule contaminants, is to develop contamination-tolerant anodes for use in this fuel cell system. Thus, the goal of this project is to overcome the poisoning problems encountered in using platinum metal-based electrocatalysts in proton exchange membrane fuel cells supplied with hydrogen fuel derived from steam-reformed methanol. Phase I will investigate the feasibility of using novel metal oxide anodes which are not sensitive to the presence of small organic molecule contaminants or other impurities for the oxidation of hydrogen gas. It is only recently that metal oxide electrodes have been used for hydrogen evolution as well as hydrogen oxidation in acidic and alkaline solutions. Tafel slopes of 40 mV/decade of current density and exchange current densities approximately one order of magnitude lower than platinum have been reported for these materials.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result of this approach, if the project is successful, is the development of novel contamination-tolerant anodes for proton exchange membrane fuel cells. These will allow the use of methanol reformate as a fuel feed gas for low-temperature fuel cells such as the proton exchange membrane system. Proton exchange membrane fuel cells have considerable value as electric vehicle power sources. Other applications for proton exchange membrane fuel cells include portable power sources for communications and news gathering equipment, portable medical instrumentation used by rescue teams, and applications that require emergency or back-up power sources or pulse power.

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Metal Carbide Nanoclusters for Polymer Electrolyte Membrane Fuel Cells--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033; (303) 940-2301
Dr. Ronald L. Cook, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-94ER81882
Amount: $75,000

Polymer electrolyte membrane (PEM) fuel cells are promising candidates for localized power generation and transportation applications because of simplicity of design, low weight, and low temperature operation. Although hydrogen based PEM fuel cells are considerably more advanced, direct methanol PEM fuel cells have better long term commercialization potential because of their high energy densities and ease of storing methanol, a liquid fuel. Distribution and marketing of methanol fuels could be accomplished by the existing infrastructure for gasoline. Unfortunately, the promise of direct methanol fuel cells is unrealized because of the lack of stable, high performance, low cost electrocatalytic materials for methanol oxidation. Only very highly loaded (and therefore very expensive) platinum/ruthenium electrocatalysts have shown high and sustained activity for methanol oxidation under fuel cell conditions. This project will prepare and evaluate a recently discovered new class of materials as electrocatalysts for methanol oxidation in a direct methanol PEM fuel cell. These newly developed materials are molecular metal carbide clusters that may exhibit unique catalytic and electrocatalytic properties. In Phase I a series of metal carbide cluster compositions will be prepared and evaluated for their activity as methanol oxidation electrocatalysts. Phase II research will be directed towards optimization of electrode composition, catalyst loading, and cell designs using these materials for direct methanol PEM fuel cell power sources.

Anticipated Results/Potential Commercial Applications as described by the awardee: Novel molecular metal carbide clusters prepared in this project may exhibit activity for the methanol oxidation reaction. Low cost, stable, high activity methanol oxidation catalysts for PEM fuel cells would allow the use of direct methanol cells across both civilian and military sectors of the economy.

IMPROVED FORMABILITY OF MAGNESIUM ALLOYS FOR AUTOMOTIVE APPLICATIONS

18

A Superplastic Oxide Dispersion Strengthened Magnesium Alloy for Automotive Applications--
Chesapeake Composites Corporation, 239 Old Churchman's Road, New Castle, DE 19720; (302) 324-9110
Mr. Eric M. Klier, Principal Investigator
Dr. Alexander Brown, Business Official
DOE Grant No. DE-FG05-94ER81728
Amount: $74,350

Reduction of automobile weight is an important approach to reducing fuel consumption. Magnesium alloys would offer the potential for significant weight reductions if they were more readily formed and their stiffness could be increased. High strain rate superplastic forming offers a cost effective route for the production of automotive components. However, to be superplastic, magnesium alloys must possess a unique set of microstructural features. Magnesium alloy systems which possess such microstructures are not readily available. Recently a new class of low cost, corrosion resistant, oxide dispersion strengthened (ODS) magnesium alloys have been synthesized by a novel liquid metal process. These materials meet the microstructural requirements for superplasticity and based on previous research, should be superplastic at strain rates consistent with conventional forming processes (10^0 to 10^1/s). These ODS alloys also offer a 45 to 190% increase in stiffness compared to conventional magnesium alloys. During Phase I, ODS magnesium alloys will be produced, extruded, and tensile tested at elevated temperatures and a variety of strain rates to determine if they are indeed superplastic.

Anticipated Results/Potential Commercial Applications as described by the awardee: If ODS magnesium is superplastic at high strain rates, it represents a generic approach to the production of low cost, high performance magnesium alloy systems which can be economically formed into automotive components. These components would reduce the weight of automobiles, improving their fuel efficiency and thereby reducing our dependence on foreign oil.

INDUSTRIALIZED PASSIVE SOLAR BUILDINGS

19

Modular/Transportable Classroom Structures--
Aspen Systems, Inc., 184 Cedar Hill Street, Marlborough, MA 01752; (508) 481-5058
Dr. Roy Richard, Principal Investigator
Dr. Kang Lee, Business Official
DOE Grant No. DE-FG02-94ER81711
Amount: $75,000

This project will design and develop a new breed of energy efficient modular/transportable classrooms that will incorporate daylighting, passive solar techniques, natural ventilation, and solar water heating. The product will be based on innovative construction techniques and technologies resulting in an energy efficient and physically and psychologically healthful environment for the students and teachers. The changing demographics throughout the country cause many school systems to experience significant fluctuations in student population resulting in an immediate, and possibly only temporary, need for more classroom space. Each year in the United States, tens of thousands of transportable classroom modules are used as a means of rapidly providing the required space at a reasonable cost. Significant energy savings can be realized in these structures through the incorporation of state of the art materials and solar energy utilization. The Phase I effort will focus on the development of solar lighting, heating, and ventilation, and their integration into a modular structure. Emphasis will be placed on ergonomics and economics to assure a user friendly, affordable classroom. The Phase II program will pursue the detailed design, fabrication, and performance testing of a full scale prototype.

Anticipated Results/Potential Commercial Applications as described by the awardee: In addition to the tens of thousands of modular classrooms that are used each year, many other uses are possible, such as for offices, day care facilities, laboratories, cafeterias, dormitories, and stores, all of which exist in both the private commercial sector and within the various branches of government.

20

Design and Evaluation of Energy Efficient Modular Classroom Structures--Modern Building Systems, Inc., P.O. Box 9493, Porter Road, Aumsville, OR 97325; (503) 749-4949
Mr. James Stanard, Principal Investigator
Mr. Donald Rasmussen, Business Official
DOE Grant No. DE-FG03-94ER81814
Amount: $75,000

The objective of Phase I of this project is to develop innovations that will enable modular classroom builders to improve the energy performance of their classroom modules while adding only reasonable first costs to the project. To achieve this objective detailed computer simulations will be performed on the various innovations to gauge their improvements over baseline statistics gathered from existing modular classrooms in a variety of climatic regions of the United States. These innovations will center around modifications to existing thinking and technology in ventilation, ventilation pre-heating, and daylighting as well as wise use of high and low peak load energy usage data through automatic control systems that will not only be user friendly but help to eliminate user control error, thus saving energy. These design modifications will improve not only the energy performance of the classrooms but improve or enhance the thermal comfort, ease of transportation, flexibility of use, and the psychological well being of the students and teachers.

Anticipated Results/Potential Commercial Applications as described by the awardee: The impact of these types of innovation on the market in the energy-conscious Pacific Northwest could be significant. They could become a voluntary requirement of most, if not all, school districts in the region. That could translate into 200 to 300 classrooms per year. At an average value of $30,000 per classroom, the market potential even in this small area is very exciting. In the Nation as a whole these innovations could be beneficial to thousands of school districts through many manufacturers. Specific groups that might be expected to use the projected results include public and private school districts across the country, including elementary and secondary schools, community colleges, universities, and churches. The results of this study will provide data that would lead to a Phase II project and actually place prototype buildings for testing at various schools in many climate regions.

21

An Integrated Anamorphic Daylighting Roof Aperture (ADRA) System Based on Non-Imaging Optical Components--Physical Optics Corporation, 2545 West 237th Street, Suite B, Torrance, CA 90505; (310) 320-3088
Dr. Tomasz Jannson, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-94ER81828
Amount: $74,990

There are three emerging technologies that can significantly advance state-of-the-art daylighting systems for interior illumination. This project will develop a non-tracking, integrated Anamorphic Daylighting Roof Aperture (ADRA) system that will incorporate each of these technologies. This system will be based on the integration of new non-imaging optical components and low-loss plastic fibers for delivering solar light to building interiors. The first new component will be an anamorphic non-imaging light collector which transforms elliptical beams into circular beams and achieves the theoretical limit of Liouville's concentration principle. Only anamorphic concentrators can effectively collect solar light for different latitudinal and azimuthal solar angles without mechanical tracking. Additionally, non-imaging collectors will also be used as beam expanders in the building's interior. They will be combined with unique holographic non-Lambertian beam-shaping diffusers. These diffusers can improve lighting efficiency by distributing light to only a selected limited solid angle, which is optimum for office illumination. These diffusers do not exhibit any significant back scattering losses and can be mass replicated using low cost embossing techniques. Phase I will combine these components with low-loss plastic fibers to produce efficient compact daylighting systems, which can be readily incorporated into roof structures. The resulting ADRA system will be modular and versatile which will make it ideally suited for integration with electrical and heating, ventilating, and air conditioning systems and electronic networks.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful completion of this project will produce inexpensive durable daylighting systems for new and existing buildings. They can provide significant energy savings and have a positive environmental impact through the use of solar energy.

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Design of a Family of Advanced Prototype Passive-Solar Modular Classrooms--Steven Winter Associates, Inc., 50 Washington Street, Norwalk, CT 06854; (203) 852-0110
Mr. Steven Winter, Principal Investigator
Ms. Marie Costello, Business Official
DOE Grant No. DE-FG05-94ER81870
Amount: $75,000

This Phase I research effort will integrate three separate disciplines to develop high-performance passive-solar modular classrooms: architectural design, passive solar systems, and modular production technology. Historically, no program or project has applied such integration to educational facilities. Even though the necessary skills have been available, no research sponsor has allocated the necessary resources. This project will use in-house specialists to develop prototype designs, supported by technical committees of the Modular Building Institute and the Passive Solar Industries Council. Completed designs will then be subjected to rigorous energy performance and life-cycle cost analyses to verify cost/benefit. Final designs for a family of passive-solar modular classrooms will be prepared, suitable for subsequent construction, testing and commercialization of prototypes.

Anticipated Results/Potential Commercial Applications as described by the awardee: If the project is successful a system of innovative passive-solar modular classrooms will have been designed, analyzed as to effectiveness, and tested to prove performance. Details of the design and its performance will be made available to members of the Modular Building Institute, who are responsible for modular classroom construction nationwide, and design/production consortia will be formed for widespread commercialization. This will positively impact the annual production of an estimated 30,000 modular classrooms, and is expected to lead to the purchase of many more modular classrooms once their potential customers are made aware of energy performance, comfort, and life-cycle cost benefits.

WIND TURBINES: EFFICIENCY IMPROVEMENT USING ADVANCED POWER ELECTRONICS

23

A Look-Ahead Adaptive Control System (LACS) for Wind Turbine Generators--AeroVironment, Inc., 222 East Huntington Drive, Monrovia, CA 91016; (818) 357-9983
Dr. Paul B. MacCready, Principal Investigator
Mr. Thomas Zambrano, Business Official
DOE Grant No. DE-FG03-94ER81700
Amount: $74,999

Existing control systems for pitch-controlled wind turbines stabilize rotor power by adjusting blade pitch in response to over-or-under power conditions in a feedback loop. The pitch control mechanism lags behind the rotor power variations that are being controlled. The time lag causes power output fluctuations that necessitate over-dimensioning of rotor, transmission, and generators to obtain a satisfactory service life. Also, it causes frequent start-stop cycles when the wind speed fluctuates about the cut-in point. An innovative look-ahead acoustic wind speed and turbulence sensor will be used to eliminate the time lag. The adaptive control system will pitch the rotor blades in anticipation of a gust (feed-forward), rather than after its arrival. The resultant more stable rotor power removes the need for down rating of the equipment leading to greater energy capture and fewer start-stop cycles. Feed-forward control is inherently stable. This feature is crucial, because it drastically reduces the difficulty of implementing expert systems for adaptive control. The adaptive controller itself, is designed to influence blade pitch without becoming part of the stability-sensitive pitch control feed-back loop. Thus, the Look-Ahead Adaptive Control System (LACS) can be retrofitted to existing machines, without affecting their existing control systems. Phase I is dedicated to proof of concept testing. Control algorithms are developed using computer simulation. They are tested by using an existing acoustic wind sensor facing upwind from the foot of the tower of the wind turbine used for testing. In Phase II, the system will be developed into a compact unit for commercial installation on the hub of wind turbines.

Anticipated Results/Potential Commercial Applications as described by the awardee: The wind speed and turbulence data provided by the look-ahead acoustic sensor permit the adaptive controller to minimize reduced energy capture by the wind turbine caused by lack of tuning. The reduction in rotor power fluctuations allows operation of the generator at increased power or, at unchanged power rating, it will extend component fatigue life. The number of start-stop cycles will be reduced.

24

A Resonant Converter for Universal Wind Application--Electronic Power Conditioning, Inc., 1895 Northwest Ninth Street, Suite A, Corvallis, OR 97330; (503) 753-7220
Dr. Hian K. Lauw, Principal Investigator
Mr. Dallas A. Marckx, Business Official
DOE Grant No. DE-FG03-94ER81747
Amount: $72,289

With a variable-speed generation (VSG) system, a wind turbine can turn at any speed and still produce constant frequency and voltage power which is compatible with the grid. The primary benefits of VSG include increased energy production, increased power capacity, soft-starts, control of torque perturbations, dynamic electrical braking, and power factor control. All of the modern techniques for implementing VSG rely on a power electronic converter or conditioner. Conventional converters have several well-known problems: high cost, excessive power losses, harmonics losses and winding damage in the generator, poor power factor, and audible noise. An innovative resonant converter known as the unipolar series resonant converter (USRC) would make dramatic improvements in each problem area. The USRC uses thyristors with zero voltage and current switching, thus minimizing losses and cost. It is also inherently bi-directional and produces sinusoidal voltage within IEEE 519 standards at both the input and output, thus eliminating supplemental filters, audible noise, and winding deterioration. In Phase I, a 400 kW USRC that can be used widely in many types of variable-speed wind turbines will be designed and assessed as to feasibility (performance and cost). In Phase II, the design will be assembled and installed in the field in an advanced wind turbine.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned resonant converter attacks directly the problems with existing converters used in wind systems today. When implemented with a flexible, universal control interface, it can be widely applied in almost any wind turbine system to enable variable speed operation. It will be marketed widely to the wind industry. This technology will also be used in adjustable-speed drives, photovoltaic systems, fuel cell systems, battery storage systems, frequency changers, and actuators.

25

A Versatile, Technically Accessible Wind Turbine Controller--Electronic Power Conditioning, Inc., 1895 Northwest Ninth Street, Suite A, Corvallis, OR 97330; (503) 753-7220
Dr. Hian K. Lauw, Principal Investigator
Mr. Dallas A. Marckx, Business Official
DOE Grant No. DE-FG03-94ER81745
Amount: $74,861

Two broad deficiencies in controls are apparent in the wind industry. The first is that a significant number of advanced wind turbine designers simply do not have controls that are adequate to compete in the wind industry. This is understandable since the strengths of most wind turbine designers fall in the area of machines, structures, and aerodynamics. The second is that most wind turbine controllers do not use the most advanced control techniques, such as rule-based algorithms, expert systems, and fuzzy logic, nor do they contain the most up-to-date digital control components, such as applied specific integrated circuits, digital signal processors, and field programmable gate arrays. Specific problems include (1) a cost several times more than it should be, (2) insufficient speed and complexity for current and future requirements, (3) doubtful reliability, (4) awkward interfaces with a system control and data acquisition (SCADA) system, and (5) the inability of the turbine supplier to support his product adequately by being able to understand and adapt the controller. This project will develop a reliable, responsive, low cost, fully integrated control system for advanced wind turbines that can be understood and modified by a single control engineer with generally available skills. The control system will contain the most advanced control concepts and the most advanced digital control hardware. In Phase I, the first step will be taken toward this objective by designing the hardware and software structure of the single turbine control and a compatible SCADA system. In Phase II, these would be assembled and tested in the field on at least two operating, advanced wind turbine designs.

Anticipated Results / Potential Commercial Applications as described by the awardee: The expected result is that all wind turbine designers would have a versatile, practical, state-of-the-art controller at reasonable cost. This need would be satisfied for a significant number of identifiable designers of advanced wind turbines who are now without such a controller. Because of the open architecture and technical accessibility of the proposed controller, it might become a standard in the industry. Since the control and SCADA requirements of other energy systems, such as dispersed engine generator sets, are quite similar, the controller would be used widely outside of the wind industry.

26

Wind Turbine Power Electronics with Hybrid Integrated Circuits--R. Lynette and Associates, Inc., 15042 Northeast 40th Street, Suite 206, Redmond, WA 98052-5353; (206) 885-0206
Dr. T. S. Jayadev, Principal Investigator
Mr. Robert Lynette, Business Official
DOE Grant No. DE-FG03-94ER81840
Amount: $74,863

Recent progress in hybrid power integrated circuit (IC) development can be taken advantage of in the design of new, innovative power electronic variable-speed systems for wind turbines. The continued advancement of these power ICs into larger rating and lower prices is assured because of the vast market in the adjustable AC drive business. The planned system employs these devices in a direct-drive (i.e., no gearbox) power electronics package that solves the current problems with variable-speed systems: high complexity and cost of the power devices and large power losses associated with variation of rotor speed over too high a range. A unique power electronics/generator scheme is planned in Phase I to significantly reduce the power requirements and complexity of the power electronics, resulting in reduction in capital cost.

Anticipated Results / Potential Commercial Applications as described by the awardee: This generator power electronics technology will contribute significantly to reducing the cost of energy (COE) from wind power plants. In concert with the improvements in the aerodynamic performance, the new scheme offers the potential to reduce COE below 4 c/kWh. If this cost goal is met, DOE estimates that there will be a 100-fold increase in wind power generation, with installed capacity of 120,000-160,000 MW.

ON-SITE REMEDIATION OF CONTAMINATED MEDIA

27

Removal and Recovery of Mercury from Contaminated Waters--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Dr. Daryl Roberts, Principal Investigator
Dr. Michael D. Durham, Business Official
DOE Grant No. DE-FG02-94ER81691
Amount: $74,881

Removal of mercury from contaminated waters is a continuing need for DOE's site remediation efforts. Some surface and subsurface discharge of contaminated water is continuing from mercury lost to the environment in the past. In the future, it is anticipated that mercury-contaminated structures and equipment will be subjected to aqueous washes, and that this water will need to be treated before discharge to the environment. Activated carbon, ion exchange resins, and derivatives of algae have been proposed for this purpose, but these techniques often remove only a small portion of the mercury and generate solid or liquid wastes from which the mercury may volatilize or be leached. The Phase I research project will investigate the feasibility of removing mercury from contaminated waters at DOE remediation sites with novel, regenerable sorbent beds. This sorbent-based technology will recover the mercury, removing it completely from the biosystem, and will allow DOE sites to ensure compliance with legislated discharge limits for mercury.The proposed sorbents have a high capacity for mercury, and the estimated capital cost of the proposed technology is no more than that of activated carbon systems used for the control of organics in waste waters.

Anticipated Results/Potential Commercial Applications as described by the awardee: The technology will make mercury removal and recovery possible for contaminated waters at DOE remediation sites, for wastes being processed by the Department of Defense, and for industrially-generated contaminated waters.

28

A Continuous High-Capacity Water Treatment Process for the Recovery of Heavy Metals--Apogee Corporation, 2501 North Loop Drive, Ames, IA 50010; (515) 292-8251
Dr. Joseph J. Hanak, Principal Investigator
Dr. Joseph J. Hanak, Business Official
DOE Grant No. DE-FG02-94ER81708
Amount: $75,000

An advanced waste-water treatment process for continuous separation of ionic species, including heavy metals, from aqueous solutions has been developed. This process shows a potential for separation of a variety of components from complex mixtures at sufficiently high capacity and low cost to be suitable for application on an industrial scale. The objectives are to provide validation and develop specific applications for the new process and to establish its competitiveness with existing processes. A demonstratration of efficient separation of heavy metals from surface mine waters is planned. The approach will be to make use of a dynamic prototype device to conduct a program of demineralization tests on heavy metal contaminants such as those found in the Berkeley Pit, an inactive copper mine in Butte, Montana. Phase I will consist of a study of the dependence of the demineralization parameters on a defined matrix of independent process parameters. It is expected that substantial gains in the rate of separation, the separation ratio, energy efficiency, and low process cost will be realized.

Anticipated Results/Potential Commercial Applications as described by the awardee: Based on results to date, a successful development of the application of the new process is expected for the removal and recovery of heavy metals from waste water and the restoration of water quality to accepted standards. Future applications will include mobile and stationary high-capacity systems (1 to 10 million gallons per day, per unit) for continuous treatment of contaminated surface water generated by mining or by manufacturing industries. Revenues from the recovered metals and water are projected to exceed process costs by a substantial margin.

29

A Biopolymer Based Selective Barrier for the Containment of Groundwater Contaminants--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033; (303) 940-2301
Dr. Kevin Gleason, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-94ER81878
Amount: $75,000

The contamination of groundwater by heavy metals, radionuclides, and organics is a serious environmental problem. In some cases it may not be possible to remove all of the material from the soil by conventional pump-and-treat techniques. In such cases, the residual material must be contained to prevent further migration. An ideal solution would be a permeable barrier that is readily installed and retains the contaminants yet allows water and innocuous ions to pass through. The objective of this project is the development of a biopolymer based permeable barrier. This system is environmentally sound and inexpensive. It can be formulated as a liquid for ease of emplacement, but once in place, it gradually hardens into a permeable solid. The resulting barrier has a high adsorption capacity for metal cations, is selective for some of the most hazardous heavy metals and radionuclides, and can also sorb anions and organics. Phase I will evaluate the sorptive capacity of the barrier material, determine formulations suitable for emplacement by conventional methods, and demonstrate the formation of a continuous barrier. During Phase I a site will be selected for a Phase II test and efforts will be focused on developing a formulation that will successfully address problems associated with that site. The projected cost and potential effectiveness of the system will be determined. Phase II, if warranted, will systematically investigate the effects of changes in composition on the properties of the barrier, including the methods for emplacement.

Anticipated Results/Potential Commercial Applications as described by the awardee: If this project is successful, the result will be a system for treatment of contaminated groundwater that is low cost and suitable to contain contaminants in groundwater at a large number of polluted sites. The system would find use by the Government and private companies in stabilizing or containing hazardous waste sites.

30

Heavy Metal Remediation of Soil Using Permeable Chelation Barriers--TPL, Inc., 3768 A/B Hawkins, Northeast, Albuquerque, NM 87109; (505) 344-6744
Dr. Franklin O. Kroh, Principal Investigator
Ms. Patricia Cabrera, Business Official
DOE Grant No. DE-FG03-94ER81892
Amount: $75,000

Remediation of soil and groundwater to reduce heavy metal contaminants to background levels poses a serious challenge. Conventional methods are able to reduce contamination levels, but total remediation, defined as achievement of background levels of the metal, may not be economically feasible. A permeable chelation barrier containing silica gel modified to chelate heavy metals provides an economical method to attain complete remediation of contaminated soils. Silica gel will be modified by attachment of amine, polyamine, or polyamine polycarboxylate groups, yielding a solid material capable of binding ions of heavy metals including lead, chromium, cadmium, and uranium. The chelating gel then is contained in a permeable fabric, and placed in a trench surrounding moderately contaminated soil, where it functions with minimal maintenance, requiring only periodic monitoring of metal concentration. When metal capacity is achieved, the barrier is removed and regenerated for further use. In Phase I such chelating silica gels containing amine, polyamine, and polyamine polycarboxylate groups will be synthesized. The metal capacity of the gels will be measured, and ease of regeneration determined. Recovery of the metals will be evaluated. Use of silica gels in permeable chelation barriers will be expanded to soil remediation in Phase II activities. The benefits of this technology include total remediation of metal contaminated soils and protection of sensitive water sources without a labor-intensive intervention. In this way, partial remediation can be accomplished in a cost-effective manner resulting in reduction of hazardous metals to background levels.

Anticipated Results/Potential Commercial Applications as described by the awardee: The benefit of this project is a low-maintenance technique to reduce metal contamination levels to background levels, while protecting groundwater sources. Commercial applications of permeable chelation barriers would be in remediation and reclamation of mine spoils, metal plating plants, and radionuclide contaminated areas.

EXPEDITED WASTE SITE CHARACTERIZATION

31

Development of Penetration Enhancement for the Cone Penetrometer Using Sonic Drilling Technology--Applied Research Associates, Inc., Box 102A, Waterman Road, South Royalton, VT 05068; (802) 763-8348
Dr. Wesley L. Bratton, Principal Investigator
Mr. Scott E. Blouin, Business Official
DOE Grant No. DE-FG02-94ER81709
Amount: $74,830

In this project, the feasibility of combining sonic drilling and cone penetration technologies will be evaluated and a set of preliminary design drawings developed. Sonic drilling technology has recently been demonstrated at the Hanford Site, WA. The results of the demonstration proved that small diameter monitoring wells could be installed to the desired depth in a rapid manner using this technology. Production rates were nearly double those of the standard cable tool methods used, which resulted in a significant cost savings. Cone penetration technology (CPT) has had limited success in penetrating the gravel formation of the Hanford Site. At areas where the CPT has been able to penetrate, a significant cost saving has been realized. Typical costs for the CPT at Hanford are $65/ft compared to $800/ft for cable tool drilling. Given the number of investigation and monitoring wells required at the Hanford and other DOE sites, savings of tens of millions of dollars will be realized using the sonic-CPT method. By developing this technology, the utility of the CPT can be extended to deeper depths and more locations at both Hanford and other DOE sites. In addition, the development of larger probes and sensors will require this technology to reach the depths of current CPT sized probes. The end result of Phase I will be a set of design drawings which can be used to fabricate a prototype for evaluation in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase I will result in preliminary design drawings of a sonic-CPT system. These drawings will be used in Phase II to fabricate and evaluate the system. Based on the results of a field demonstration, a final design will be determined, and commercial units can be developed. These units would then be available to expand the role of hazardous site investigations at the DOE sites, especially the Hanford and Savannah River Sites.

32

A New Semiconductor Radiation Sensor for Expedited Waste Site Characterization--Aurora Technologies Corporation, 7408 Trade Street, San Diego, CA 92121-2410; (619) 549-4645
Dr. F. P. Doty, Principal Investigator
Dr. J. F. Butler, Business Official
DOE Grant No. DE-FG03-94ER81714
Amount: $74,922

The overall goal is to develop low cost "smart" sensors for hard x-rays suitable for use with minimally intrusive emplacement systems such as cone penetrometers and portable instruments. The sensors will efficiently measure energy spectra up to 300keV, an important range for spectroscopic determination of the actinide radioisotopes and for x-ray fluorescence of heavy metals. The sensors will incorporate recent advances in cadmium zinc telluride (CdZnTe) detector technology, smart sensor technology, and x-ray spectral analysis techniques and electronics. Sensor capabilities will include: 1) localization of radionuclide contamination, 2) quantification by spectral analysis, and 3) analysis of soil properties and heavy metal contamination. The sensors will provide significant advantages over existing room temperature technology, including improved energy resolution, small size, low power operation, and solid state reliability and ruggedness.

Phase I will establish feasibility by analyzing preliminary detector response characteristics, and will furnish improved pulse readout electronics, methods for quantitative interpretation, and engineering parameters required to build a Phase II prototype sensor.

Anticipated Results/Potential Commercial Applications as described by the awardee: The program should result in commercially available, low cost, smart x-ray sensors useful to both the private and public sectors for environmental monitoring, nuclear safeguards, oil and mineral exploration and other applications. This new sensor technology may have significant export business potential, and provide real benefit to the nation's economy.

33

A Micromachined Chemical Analysis System for Waste Site Characterization--Berkeley Micro-Instruments, Inc., 1301 South 46th Street, Building 164, Richmond, CA 94804; (510) 231-5710
Dr. Stuart W. Wenzel, Principal Investigator
Dr. Ben J. Costello, Business Official
DOE Grant No. DE-FG03-94ER81715
Amount: $74,351

The identification and quantification of toxic chemicals is essential for the cost-effective remediation of hazardous waste sites. The development of a chemical microinstrument is proposed for environmental analysis: a silicon chip containing multiple micromachined components that work together to attain the high selectivity and sensitivity characteristic of conventional analytical instruments. This chip will be the enabling technology for handheld chemical analyzers that are user-friendly, inexpensive, and battery operated, yet have the power to perform the sort of chemical analysis that now requires expensive, fragile laboratory instruments. The aim in Phase I will be to design and build critical components of the micromachined chip. The circuitry and algorithms to control the individual chip elements will be designed and tested, and tests will be performed to evaluate the validity of the approach and to guide further development.

Anticipated Results/Potential Commercial Applications as described by the awardee: This technology should be broadly applicable to in situ waste site characterization, "smart" cone penetrometers, feedback-control of waste-remediation processes, classifying waste products in known storage facilities, personal chemical-exposure monitoring, and indoor-air-quality monitoring.

34

A Personal Computer Window-Based Systematic Hazardous Waste Management Evaluator (SHOWME) for Waste Site Data Processing--Consultants for Environment System Technologies, 10 Damara Street, Irvine, CA 92714; (714) 724-9908
Dr. Sumant K. Gupta, Principal Investigator
Dr. Sumant K. Gupta, Business Official
DOE Grant No. DE-FG03-94ER81731
Amount: $75,000

At a cost of billions of dollars, nationwide field and laboratory investigations are being performed to characterize and clean the contaminated DOE and DOD facilities and several Superfund sites. A dynamic interactive Systematic Hazardous Waste Management Evaluator (SHOWME) is planned in Phase I to (1) systematically summarize and display geologic, hydrologic, and chemical data, (2) execute statistical tools to facilitate in-field, step-wise, dynamic planning and execution of site characterization activities, and (3) quantitatively evaluate transport of chemicals. The data processing module of the software package will generate self explanatory data summaries, concise display of each monitoring station information, and three dimensional interactive visualization of the given site geo-hydrologic system and contaminations. Interface with statistical analysis tools will facilitate consideration of geologic layers, anisotropy, trends, correlation geostatistics, and site specific models. SHOWME pre- and post-processors for interface with three dimensional finite element flow and transport code will (1) simulate complex geometry of waste site geologic systems, (2) provide tools to evaluate alternative remedial measures, and (3) perform sensitivity analyses for likely benefits of proposed additional site characterization. The software package will be based on a modern window type graphical interface to maximize user friendliness. Each key dialogue box, pull-down menu, and interactive option will include instant display of instructional window and help keys. In summary, SHOWME will provide the means to systematically process the data collected, maximize the use of available information, minimize the investigation cost by timely visual display of information, and expedite site characterization.

Anticipated Results/Potential Commercial Applications as described by the awardee: SHOWME interactive software tools will provide an easy, elegant means to process, analyze, and visualize several megabytes of site characterization information. SHOWME output will facilitate (1) systematic interpretation of geologic, hydrologic, and chemical contaminants, and (2) timely and sound decision-making for field managers, decision makers, and regulators. SHOWME code has several potential uses by federal, state, and public agencies; landfill operators; environmental consultants; regulators; and the petrochemical industry. Efficient, timely processing of information and enhanced understanding of contaminant distribution are likely to reduce site characterization costs by millions of dollars.

35

Electrocore Electrokinetic Core Sampling and Monitoring--ISOTRON Corporation, 13152 Chef Menteur Highway, New Orleans, LA 70129; (504) 254-4624
Mr. Richard A. Graves, Principal Investigator
Mr. Henry L. Lomasney, Business Official
DOE Grant No. DE-FG05-94ER81790
Amount: $73,098

It has been found that trace metals that previously were not detected as present in soil samples can be concentrated at detectable levels. This project will tailor current electrokinetic technology to design an innovative soil sampling and monitoring method involving an in-situ sorbing of trace contaminants from the soil by concentrating them into a solid matrix under the influence of an applied potential over a limited time interval. Two design concepts are planned for both fabrication and experimentation for the electrokinetic soil sampling and monitoring apparatus. One design comprises fabricating both anode and cathode into a 1 to 1.5 inch polymeric cylinder which is capable of concentrating both anions and cations into an easily analyzable matrix. The other design has an independent anode and cathode and is capable of not only concentrating the contaminants but also of in-situ determination of the target species. Both designs also have the potential of being used for estimating ion mobility and soil retention times.

Anticipated Results/Potential Commercial Applications as described by the awardee: The technology produced by this research will allow profiling and monitoring of contaminant levels in soil even at very low concentrations. The technology will provide a safe, easily installed, low maintenance sampling system requiring low exposure of work personnel to hazardous conditions.

LOW-LEVEL MIXED WASTE PROCESSING

36

An Acoustic Plate Mode Aqueous Mercury Sensor--BIODE, Inc., 2 Oakwood Road, Cape Elizabeth, ME 04107, (207) 883-1492
Dr. Douglas McAllister, Principal Investigator
Dr. Douglas McAllister, Business Official
DOE Grant No. DE-FG02-94ER81717
Amount: $74,600

There is a critical need for a fast, simple sensor for aqueous mercury in waste, surface, and ground water. This sensor is required for the DOE remediation efforts as well as the more widespread efforts in environmental protection. Such a sensor should be able to react to nanogram per milliliter levels of mercury. The sensor is capable of direct immersion in solution and should provide continuous data on either cumulative mercury exposure or instantaneous concentration. Spectroscopic methods, such as atomic absorption, atomic emission, and atomic fluorescence provide adequate sensitivity; however, these are discrete laboratory techniques and cannot be employed for continuous monitors or in the field. One method of detecting ppb to ppm levels of mercury in solution involves the use of novel class of piezoelectric sensors, known as the shear horizontal acoustic plate mode (SHAPM) sensor. These sensors measure the perturbation of acoustic wave, in situ, to changes in electrical and mechanical properties. They are readily operated in contact with a fluid medium and are sensitive to subnanogram quantities of mass adsorbed onto their surface. The SHAPM has the potential to rival cold vapor atomic absorption and atomic fluorescence spectroscopy techniques, while simultaneously offering in-situ, continuous monitoring. The monitor is expected to provide a measure of the mercury concentration in minutes and to be reusable many times. Phase I will demonstrate the principal of operation of the new sensor to detect nanogram per milliliter levels of mercury in solution. This effort will include the fabrication of several devices with different films which are expected to confer specificity for mercury. Responses of the sensors will then be measured over various mercury concentrations. Effects of possible interferents will also be examined. Phase II will concentrate on optimization of the most promising device which will include aspects such as durability, reusability, signal processing, and packaging.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project should lead to field- and factory-based monitoring instruments for aqueous mercury which will be capable of performing discrete, in-situ measurements of mercury. Although not directly addressed, other films could be developed for the selective detection of other metal contaminants (e.g., cadmium or uranium), volatile organic compounds (VOCs) or gaseous pollutants (e.g., NO_x, SO_2, or H_2S).

37

An Off-Line-Locked Laser Diode Sensor (OLDS)--Spectral Sciences, Inc., 99 South Bedford Street, #7, Burlington, MA 01803-5169; (617) 273-4770
Dr. Jamine Lee, Principal Investigator
Dr. Fritz Bien, Business Official
DOE Grant No. DE-FG02-94ER81865
Amount: $75,000

Secondary waste stream monitoring requires real-time/continuous measurements of hazardous gas species. Although baseline techniques using gas filter correlation and ion-selective electrodes have been demonstrated for monitoring hydrogen chloride off-gas at a hazardous waste incinerator, none of these techniques are suitable for monitoring corrosive or reactive gases such as hydrogen fluoride. An off-line-locked laser diode sensor which will provide automatic, unattended, real-time, in-situ monitoring of selected toxic gases will be developed in Phase I. The instrument extends current laser absorption technology to the measurement of unstable gas species in harsh stack conditions. The technique provides active control of the laser emission without use of a sample molecule for reference, which can be chemically unstable and physically unsafe for the instrument operation. This will provide performance and cost advantages in the detection of a large number of toxic species, including hydrogen fluoride, hydrogen chloride, hydrogen bromide, carbon dioxide, carbon monoxide, nitrogen dioxide, hydrogen cyanide, and hydrogen sulfide at concentrations ranging from below the threshold level to well above the acute damage level.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned sensor can be used for continuous emission monitoring of hydrogen fluoride and other corrosive and reactive gas species in numerous applications. These include monitoring waste off-gas from incineration plants, petrochemical processing, and detecting accidental toxic emissions in industrial processes. Further development could lead to extensions to more complex applications, including monitoring of multiple species using a single common probe. This sensor offers significant advantages in terms of cost, size, and automation over currently available baseline techniques and commercial instruments for waste stream off-gas monitoring.

ARMS CONTROL AND NONPROLIFERATION VERIFICATION AND DETECTION TECHNOLOGY

38

Microdevices for Proliferation Detection--Deacon Research, 2440 Embarcadero Way, Palo Alto, CA 94303; (415) 493-6100
Dr. William Bischel, Principal Investigator
Dr. Olive Lee, Business Official
DOE Grant No. DE-FG03-94ER81736
Amount: $75,000

There is a need in the arms control community for a compact, low cost, sensitive sensor for remote detection of the products of proliferation activities. This project is concerned with a sensor based on the microchip capillary electrophoresis (CE) and high performance liquid chromatography (HPLC) technology recently developed at Oak Ridge National Laboratory (ORNL). This potentially battery-powered sensor would be capable of inorganic ion detection in the field for arms control verification, as well as numerous other government and commercial chemical sensing applications. Development of the laser diode based light source is being pursued, and the fabrication of the separation columns has already been demonstrated at ORNL. Phase I is expected to eliminate the key remaining risk in the development of this sensor-the optical detection system. Phase I should result in the fabrication of the detection system and the measurement of the fluorescence of a test analyte. A collaborative effort with ORNL will begin to design a prototype of the integrated microchip sensor that will be fabricated and tested in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of a miniature chemical sensor is anticipated, for use as a rugged field instrument for chemical analysis, a long-lifetime sensor for manufacturing process control, or a chemical analyzer for laboratory use.

39

Human Presence Detection in Vehicles--ENSCO, Inc., 5400 Port Royal Road, Springfield, VA 22151-2301; (703) 321-9000
Dr. Thomas A. Gamble, Principal Investigator
Dr. Norman Bush, Business Official
DOE Grant No. DE-FG05-94ER81758
Amount: $74,998

An existing system has demonstrated, in quiet conditions, very reliable detection of humans hidden in vehicles. Seismic vibrations are the major, unavoidable limitations. Measurement of the seismic vibrations and coherent analyses will be utilized to compute and subtract the effect of the seismic interference on the vehicle motion. The Phase I effort will improve the reliability, increase the search rate, and expand the conditions under which the system can operate. Data will be collected, optimized statistical techniques will be defined for the subtraction of seismic noise interference, and the detection algorithm will be enhanced. The requirements for a field test system incorporating these enhancements will be defined.

Anticipated Results/Potential Commercial Applications as described by the awardee: The subtraction of the seismic interference should enable reliable human presence detection in vehicles at all locations. The security and effectiveness of entry/exit portals is a concern at military and classified facilities, especially rapid reaction force facilities in foreign countries. This will become more common in a world of sustained, low intensity conflict and long term peace-keeping missions. Border check points, prisons, commercial firms, and residential buildings also often require vehicle inspections for unauthorized personnel.

40

Reliable Intrusion Detection--ENSCO, Inc., 5400 Port Royal Road, Springfield, VA 22151-2301; (703) 321-9000
Dr. Thomas A. Gamble, Principal Investigator
Dr. Norman Bush, Business Official
DOE Grant No. DE-FG05-94ER81757
Amount: $74,998

Reliable intrusion detection may be achieved by combining generalized potential function (GPF) neural net construction and multiple sensor data fusion. Traditionally, reliable intrusion detection can be difficult because noise levels change with time and location, and an intrusion may produce a wide range of signals or variations over the different types of sensors. Accommodating these variations is not practical using standard classification techniques. A self-organizing classification technique, such as a neural net, provides a means for learning the idiosyncrasies of a particular location and fully utilizing data from various intrusion detection sensors (seismic, acoustic, electromagnetic, temperature, pressure, etc.). Many methods of neural net construction have been developed. Most have deficiencies for intrusion detection. An impractical number of training instances may be required, or the confidence of detection may not be reliably indicated. The GPF method of neural net construction has demonstrated a superior ability to characterize complex classes and to quantify the confidence of classification. The Phase I effort will set up a testbed including a variety of sensors, and will monitor/record all sensor outputs simultaneously as simulated intrusions occur. The recorded data set will be used to train and test the GP net intrusion detection algorithmic formulation. The false alarm rate and probability of detection will be compared to those of the individual sensors, and this approach will be optimized for Phase II. In Phase II, a field test prototype system will be developed, incorporating real-time training of the GP net classifier and real-time intrusion detection. The performance of this system will be evaluated using simulated intrusions. A production system will be produced and installed during Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: This system will provide more reliable intrusion detection for sensitive nuclear facilities. Physical security is a major concern at many facilities other than nuclear. All military and classified facilities have to effect some sort of entry control. Many civilian activities also require intrusion detection. International borders are an important example. Many commercial and residential buildings and sites also restrict access for security reasons and could provide a large commercial market for a reliable, convenient device.

41

Human Presence Detection Based on Imaging Sensors and Image Processing and Analysis--Physical Optics Corporation, 20600 Gramercy Place, Suite 103, Torrance, CA 90501; (310) 320-3088
Dr. Wayne Lian, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-94ER81829
Amount: $74,976

Existing human presence detection systems suffer from high false alarm rate and limited programmability because they lack intelligent signal processing. A system based on image processing and analysis technique will address these problems. The image data is acquired by an infrared imaging sensor and a charge-coupled device (CCD) camera. Motion detection and pattern recognition are employed to detect human presence. In addition, the system incorporates an innovative signs-of-life detection technique, based on detecting micro-motions of breathing, eye blinking, and head turning. Data fusion reduces false alarm rate. The Phase I work will establish the feasibility of the proposed approach. Algorithms for motion detection and pattern recognition will be implemented in a personal computer. The effectiveness of the signs-of-life detection will be evaluated experimentally using human subjects, a CCD camera, a CCD-to-computer interface board, and a computer for signal processing. Phase I will include an estimate of the system's detection and false alarm rates. In Phase II, an operational human presence detection system will be constructed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The proposed system has applications in guarding buildings, including storage spaces and warehouses. It is highly flexible and programmable, able to communicate with a remote operator, and cost effective.

42

Security Monitoring Systems: Sensors, Communications, and Computing--Spectrum Data, Inc., P.O. Box 3100, Kent, WA 98032; (206) 824-9337
Mr. Warren Brent Chitwood, Principal Investigator
Mr. Rod Davidson, Business Official
DOE Grant No. DE-FG03-94ER81866
Amount: $75,000

Accurate and automatic detection of human presence in order to prevent unauthorized use of high value assets is an important issue for both DOE and society in general. To date, security systems have been very expensive in terms of capital and very labor intensive to operate. In addition, the systems have been prone to false alarms, reducing confidence in the alarms generated. In this project a security monitoring system based on a unique combination of video acquisition, wireless spread spectrum communications, and morphological image processing to detect the presence of human intruders is planned. The ultimate goal is to reduce by a factor of 10 the capital costs and installation labor (compared to conventional security systems), reduce false alarms to near zero, produce the positive detection of humans with near 100% accuracy, and provide fully automated operation. Phase I investigates morphological image processing for human detection, implements the test bed detection system, and validates the system concept based on actual video. The software for image processing runs on a workstation or personal computer for the test bed. The software will be analyzed to determine the requirements for porting to low cost dedicated digital signal processing. Cost analysis will determine if the signal processing should be done in hardware, in software, at remote nodes, or at central hubs. Design alternatives will be suggested for changes in the image processing software or image files transferred to optimize cost and performance. The final report will provide test results, suggest design alternatives based on test results, and summarize the analysis of software and hardware requirements to develop a prototype for field testing.

Anticipated Results/Potential Commercial Applications as described by the awardee: The expected result of this project is the proof of concept that human presence can be automatically detected and confirmed with a very low false alarm rate using wireless data communication systems and advanced signal processing and can be manufactured for a low cost (under $600 a node). Controlling crime is a major issue in the United States. Currently around 9.95 billion dollars per year is spent on security systems. These monitored systems have excessive false alarm rates. With the successful completion of this system, government, business, and consumers can use a new generation of security system with near zero false alarm rate and very low installation and operating costs.

43

Detecting Human Presence Using Synchronized Omnidirectional Video and Thermal Imaging--TeleRobotics International, Inc., 7325 Oak Ridge Highway, Knoxville, TN 37931; (615) 690-5600
Mr. H. Craig Grantham, Principal Investigator
Dr. H. Lee Martin, Business Official
DOE Grant No. DE-FG05-94ER81885
Amount: $74,900

DOE is actively pursuing innovative techniques for detecting human presence in enclosed areas. This is necessary for such circumstances as personnel safety in vaults containing special nuclear materials, intrusion detection in sensitive facilities, and even automating vehicle inspection. The key objective is to eliminate false alarms while providing positive determination when a human is present. The proposed effort eliminates false alarms by combining multiple sensors, video, and thermal signature using a patented imaging technology called Omniview, coupled with custom imaging analysis, to make a positive determination. The Omniview provides video images with pan, tilt, magnify, and rotation (P/T/M/R) performed electronically, with no moving parts. It allows viewing of large fields-of-view up to 180 degrees by correcting any lens distortion, and provides multiple images from a single camera, each with dependent P/T/M/R. Integrating a visible spectrum video signal with a thermal video signal will provide an extremely positive determination, since multiple parameters and decision criteria are available. The concept will result in a wireless, battery powered unit making it covert, portable and easy to retrofit into existing facilities. In the phase I effort, the feasibility of the human detection system will be verified and proof-of-principle demonstrated, including dual-image transmission and verification of the performance of the basic subsystems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The system being developed would have numerous applications in industrial and commercial security, as well as remote surveillance of sensitive military and nuclear facilities.

44

Seismic Detection of Individuals Hiding in a Vehicle--Utah Geophysical, Inc., P.O. Box 9344, Salt Lake City, UT 84109; (801) 272-4957
Mr. Lewis Katz, Principal Investigator
Mr. Lewis Katz, Business Official
DOE Grant No. DE-FG02-94ER81895
Amount: $39,510

External monitoring devices for detecting humans hiding in vehicles are needed to prevent unauthorized access to restricted military areas and to prohibit illegal immigrants from entering the United States at border crossings. Several investigators have found that a seismometer, placed on a vehicle, can be used to detect an intruder's heart sounds. In the absence of wind noise, the observed signal level of the heartbeat exceeds background noise levels by 20 db. The vehicle's suspension system appears to amplify the heart sounds while isolating noise from the ground. Previous efforts to utilize this method have been hampered by wind noise. The wind shakes the vehicle, masking the heartbeat signals. Previous investigations have also been limited to detecting only a single individual hiding in a car or truck. Unique characteristics of heart sounds have been identified that are likely to make them more apparent in the presence of noise. This Phase I project will use innovative seismic data acquisition and processing methods to detect an individual's heartbeat and thus determine if an intruder is hiding in a vehicle. The planned method can also be used if more than one person is hiding in the vehicle.

Anticipated Results/Potential Commercial Applications as described by the awardee: Information obtained in Phase I of this study will provide data needed to develop a seismic monitoring system, capable of determining if individuals are present in a vehicle, without physically searching the vehicle. This monitoring system will be of value for military security and U.S. Border Patrol agents. There are also possible applications for this system in the medical and health industries.

INTERNATIONAL ATOMIC ENERGY AGENCY SPECIAL SAFEGUARDS INSPECTIONS

45

Plutonium Assay Using Superheated Drop Technology in Support of International Atomic Energy Agency Safeguards--Apfel Enterprises, Inc., 25 Science Park, Suite 676, New Haven, CT 06511; (203) 786-5599
Mr. Jesus D. Martin, Principal Investigator
Mr. Robert E. Apfel, Business Official
DOE Grant No. DE-FG05-94ER81707
Amount: $74,976

The end of the cold war has switched the focus from building weapons of deterrence to minimizing the chances for the use or proliferation of nuclear weapons. Thus, arms control verification and the careful monitoring of the Nuclear Non-Proliferation Treaty are essential components of any international effort to assure safety from nuclear threats and security around the world. Success in verification and monitoring are only possible if instrumentation has adequate sensitivity for the radiation type of interest and gives an unambiguous and immediate readout. There are practical requirements as well. The instrumentation should be readily portable, should be easy-to-use, and should save the radiation fluence history for later analysis. It should complement other instrumentation designed to support the Safeguards Program of the International Atomic Energy Agency. Superheated drop (bubble) technology (SDD) promises such characteristics and overcomes some of the limitations of gamma spectrometry and ^{3}He coincidence counting. Phase I consists of the research and development that will consider the feasibility of a small, microprocessor-based neutron spectrometer that will count bubble events produced by neutrons. Spectrometry will be accomplished by using SDD compositions possessing different neutron energy thresholds. This system will complement gamma spectrometry in providing immediate display of the radiation fluence and flux as well as immediate or delayed downloading of the radiation record to a compact, battery-powered personal computer. From such records, on-site inspectors should be able to make reasonable assays of the amount of plutonium present, with the possibility of differentiating between spontaneous fission neutrons and neutrons produced by α-n reactions. The entire system, which should fit in an attaché-sized case, may also find application in low-level environmental monitoring of transuranic wastes.

Anticipated Results/Potential Commercial Applications as described by the awardee: If feasibility is demonstrated, then the project will produce a compact and highly sensitive spectrometer for neutrons that will serve to alert inspectors to the presence and amount of plutonium. Such instrumentation may also have applications for short-term, low level transuranic waste monitoring and other environmental surveys of importance to DOE.

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High Energy Resolution Cadmium-Zinc-Telluride Semiconductor Radiation Detectors-- Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Rengarajan Sudharsanan, Principal Investigator
Mr. Patrick N. McDonnell, Business Official
DOE Grant No. DE-FG02-94ER81869
Amount: $74,955

There is a need for improved, miniaturized radiation detectors for on-site measurements of containers of nuclear material, particularly uranium and plutonium. Detectors currently available require cryogenic cooling (high-purity germanium) or lack the energy resolution necessary to verify plutonium accurately (sodium iodide). Cadmium telluride detectors have been a promising alternative but have suffered from materials and device problems which have prevented them from realizing their potential. Phase I should demonstrate a room temperature CdZnTe p-i-n radiation detector with sensitivity and energy resolution that is superior to current CdTe detector technology. The improvement would result from an improved mobility-lifetime product and higher intrinsic resistivity for CdZnTe compared to CdTe. Additionally, the historic ohmic contact problems of CdTe would be overcome by grading the composition of the p and n contact layers to ZnTe and CdTe, respectively. The enhanced performance of this detector will be verified by measuring the gamma ray sensitivity and energy resolution of the device using high energy radionuclide sources. Detector structure will be optimized during Phase II and prototype miniaturized probes will be built for verification of nuclear materials.

Anticipated Results/Potential Commercial Applications as described by the awardee: The Phase I project should demonstrate that, with attention to issues of material quality and ohmic contacts, CdZnTe room temperature gamma ray detectors can be fabricated with sensitivity and energy resolution superior to that of competing technologies. Applications for these detectors will include portable miniaturized probes to monitor uranium and plutonium un nuclear facilities as well as gamma spectroscopy and X-ray astronomy.

INNOVATIVE FOSSIL SOLIDS AND LIQUIDS PROCESSING AND RELATED CROSSCUTTING APPLICATIONS

47

Adaptive Control of Nitrogen Oxide Reduction Processes--Advanced Fuel Research, Inc., 87 Church Street, P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. Anthony Bonnano, Principal Investigator
Mrs. Sally E. Solomon, Business Official
DOE Grant No. DE-FG05-94ER81695
Amount: $74,945

Recent legislation in the U.S. and abroad, driven primarily by environmental concerns, has led to the development of technology to reduce the levels of nitrogen oxide (NO_x) emitted from combustion facilities. Application of this technology to coal-fired power generation facilities has been particularly important because of the relatively high nitrogen concentration of typical coals (0.5 to 2%). Selective catalytic and non-catalytic reduction (SCR and SNCR) are flue gas clean-up processes that use a reducing agent (usually ammonia or urea) to convert NO_x into molecular nitrogen and water. Although these processes can often reduce NO_x concentrations by over 90%, variations in process temperatures or improper control of ammonia injection rates can lead to increased NO_x concentrations or "ammonia slip". Ammonia slip not only defeats the goal of reduced emissions (ammonia is an air toxic), but can also cause operational problems in the plant, such as corrosion, and will contribute to ash fouling. The complexity of these processes, variability in boiler load and temperature profiles, and the difficulties associated with monitoring ammonia slip all create a difficult control problem for NO_x reduction using flue gas clean-up technology. This project will employ artificial neural networks (ANNs) to adaptively model and control NO_x reduction processes using the boiler and process parameters as input and the resulting NO_x and ammonia concentrations as output. The capability of ANNs to learn from observation, together with their inherent ability to model nonlinearity, make them ideally suited to the problem of process control in complex processes. The Phase I project will concentrate on flue gas clean-up processes, although this methodology should also be applicable to modified combustion strategies such as air staging. New ammonia monitoring technology currently under development will provide previously unavailable input data for model development.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful completion of this project would result in process control methodology for maximizing NO_x reduction capabilities while minimizing ammonia slip (or boiler inefficiency in the case of modified combustion strategies). This technology would clearly provide both economic and environmental benefits to the Nation; potential installations exist at thousands of sites in the U.S. and abroad.

48

A Molecular Dynamic Aided Advanced Diagnostic Tool for Granular Flows--Cambridge Hydrodynamics, Inc., P.O. Box 1403, Princeton, NJ 08542; (609) 683-1515
Dr. William S. Flannery, Principal Investigator
Ms. R. Karp, Business Official
DOE Grant No. DE-FG05-94ER81722
Amount: $75,000

The ever increasing need to process large quantities of solid fuels like coal provides strong motivation to study the dynamics of flowing granular materials. Laboratory experiments are hampered by the lack of adequate diagnostic tools and means to control the flows. Field experiments are very expensive as well. Also, scale dependence implies that results of laboratory or semi-industrial scale experiments may not be relevant to large scale industrial systems. Recent algorithmic advances as well as the availability of fast superworkstations enable the use of new molecular dynamic simulations to study granular systems containing up to a million particles in practically any desired geometry and for any prescribed geometrical or dynamical properties of the particles or the boundaries. The measurement of full velocity, stress, granular temperature, concentration fields, flow rates, density profiles, and other macroscopic and microscopic properties of the flows using simulation results is now possible. The large number of particles that can now be simulated enables the study of relatively large scale systems. In contrast, most previous particle dynamics computer codes could simulate a few thousand particles in a simple enclosure and a few hundred particles in complex flow situations. The existence of a new clustering scale in granular systems which indicates that the dynamical properties of small systems may be qualitatively different from those encountered in large systems has now been demonstrated. This renders simulations of systems containing a relatively small number of particles of limited applicability. The diagnostic simulation code to be developed in Phase I will be fast, user friendly and sufficiently versatile to handle variable geometries and particle and boundary properties.

Anticipated Results/Potential Commercial Applications as described by the awardee: The coal and fossil industry, power plants, and other industries worldwide can benefit significantly from reliable diagnostic and design methods. The design and operation of silos, bins, chutes, hoppers, and of many other systems will be improved, rendering them more efficient. Troubleshooting in such systems can be highly facilitated by the use of good diagnostic tools. Compliance with the Clean Air Act Amendments of 1990 will be easier while keeping energy prices at reasonable levels. State-of-the-art algorithmic methods and statistical mechanical techniques will be harnessed to achieve the goal of producing a user-friendly simulation tool and associated diagnostics for solid fuel flows.

49

Gas Separation Membranes Based on Permselective Films of Buckminsterfullerenes--CeraMem Corporation, 12 Clematis Avenue, Waltham, MA 02154; (617) 899-0467
Dr. Richard J. Higgins, Principal Investigator
Dr. Robert L. Goldsmith, Business Official
DOE Grant No. DE-FG02-94ER81724
Amount: $75,000

The selective permeation of gases through thin films of carbon-60 (Buckminsterfullerene) has been suggested as a possible application of this novel form of carbon. Indeed, substantial differences have been demonstrated in the rates of desorption of gases from crystalline powders of C-60 and C-70. Whereas various carbon adsorbents are routinely used for gas separation and carbon-based permselective membranes have been reported, no adsorbent or amorphous carbon membrane has the inherent advantage of the geometrically-fixed "pore size distribution" characteristic of fullerene crystals. Therefore, the opportunity exists for highly selective permeation behavior if these materials could be made into thin films on a practical substrate. The planned technical approach involves fabrication of films of C-60 on inorganic supports. The focus will be on a low-cost, slip casting technique that takes advantage of the solubility behavior exhibited by fullerenes in several organic solvents. This organic "slip" will be applied to a microporous layer of gamma alumina with about 2 nm pores prepared on commercial ceramic ultrafiltration membranes. This gamma alumina layer will be applied with techniques previously established. The resulting fullerene membranes will be tested for gas separation behavior and thermal stability at elevated temperatures.

Anticipated Results/Potential Commercial Applications as described by the awardee: The fullerene-based gas selective membranes to be developed, when adapted to inexpensive, high-surface-area, supports (as envisioned for Phase II work), would provide a highly efficient, new method of separating a wide range of gaseous components typically found in chemical, petrochemical, and refining processes.

50

Improving the Performance of Conventional and Column Froth Flotation Cells--CQ, Inc., P.O. Box 208, One Quality Center, Homer City, PA 15748; (412) 479-6016
Dr. Barbara J. Arnold, Principal Investigator
Mr. Clark D. Harrison, Business Official
DOE Grant No. DE-FG05-94ER81733
Amount: $74,404

Because of more stringent sulfur dioxide emission restrictions imposed under the 1990 Clean Air Act Amendments and the importance of raw coal cost and processing cost, many domestic mining companies producing higher sulfur content coals will be forced out of business for quality and/or economic reasons. This situation may force the closure of marginal operations that are vital to many state economies. However, studies indicate that many higher sulfur coals may remain acceptable as feed stocks if more efficient fine coal cleaning technologies can be developed or conventional fine coal cleaning technologies can be improved. Because of this need and since many existing coal processing facilities employ some type of conventional or column flotation circuit, improving the efficiency of these existing technologies would provide the greatest benefit. This project will investigate the effects of high-shear pretreatment of coal feed on froth flotation performance and chemical requirements. The Phase I objective is to improve Btu recovery and increase pyrite rejection while reducing chemical costs. This pretreatment will enhance collector selectivity and better disperse the collector to make these improvements.

Anticipated Results/Potential Commercial Applications as described by the awardee: By subjecting conventional or column flotation feed and/or chemical additives to high-shear pretreatment, increases in Btu recovery and pyrite rejection should occur with lower chemical additive costs. Should this be successful, coal froth flotation circuits in cleaning plants in this country and abroad could be retrofitted with the in-line high-shear treatment device. The improved efficiency of the flotation circuit could possibly allow some high-sulfur, high-cost facilities to remain competitive.

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Selective Comminution of Coal for Enhanced Removal of Mineral Matter--Energy and Environmental Research Corporation, 18 Mason, Irvine, CA 92718; (714) 859-8851
Mr. Jerald A. Cole, Principal Investigator
Dr. Roy Payne, Business Official
DOE Grant No. DE-FG03-94ER81753
Amount: $75,000

On-line processing of coal prior to combustion in pulverized coal boilers involves first crushing the bulk coal. Crushed coal is then conveyed on weigh-belt feeders to large hammer mills where it is reduced to its final size. Before delivery to the burners, the pulverized coal is aerodynamically classified in cyclones or similar inertial separators to remove larger coal particles and denser mineral matter. The pulverization process is non-selective, however, and produces fine mineral matter than can pass through the classifiers and contribute to ash fouling and emissions of toxic metals and sulfur oxides. In contrast, the selective comminution process can soften and fragment the carbonaceous matrix of crushed coal prior to pulverizing, without affecting the pyritic and quartz mineral components. This reduces the amount of energy needed for pulverization and the fineness to which mineral inclusions are ground, making the final aerodynamic classification process more effective. In contrast with density-based separation processes, such as floatation, selective comminution can be performed on-line and does not require post treatment such as washing and drying. During Phase I the effectiveness of selective comminution will be evaluated for dependence on coal type. The total amount of energy required to effect separation of mineral matter will be determined and compared with conventional practices for achieving similar levels of coal cleaning.

Anticipated Results/Potential Commercial Applications as described by the awardee: This effort will lead to the development of a process for reduction of pollutant and toxic metals emissions resulting from the burning of coal. Commercial applications for the process will be in existing and future pulverized-coal-fired power equipment. Application of this technology will not only lead to reduced emissions and resultant reductions in post-combustion cleanup costs, but will also lead directly to lower maintenance costs and longer plant life.

52

An Optical Gas Temperature Probe for High Temperature Fossil Fuel Process Streams--ERC, Inc., 205 Research Park Drive, P.O. Box 417, Tullahoma, TN 37388; (615) 455-9915
Dr. Y. C. L. Susan Wu, Principal Investigator
Mr. Richard S. Lin, Business Official
DOE Grant No. DE-FG05-94ER81762
Amount: $74,894

This project concerns an innovative concept for an optical gas temperature probe which will have the capability of making direct measurements of gas temperature in hot (>1500 K) process streams of coal combustion systems and large-scale powerplant facilities. Having the means for direct gas temperature measurements at strategic locations along a process flow path would provide a valuable tool for fossil fueled combustion systems and other applications such as power utilities, cement kilns, and waste incinerators. Direct gas temperature measurement allows characterization of the gas stream and system thermodynamic performance, providing a means for operator action to monitor, control, and optimize the system, as well as diagnose potential/hazardous problems. The Phase I technical approach is that of taking a proven optical diagnostic technique for measurement of high temperature gases (sodium line reversal) and miniaturizing the components of that technique to produce a temperature probe. This temperature monitoring system realized with the probe and its computer driven peripherals will be accurate, reliable, robust, and affordable. Phase I research will determine the feasibility of the optical gas temperature probe. It will focus on verifying the theory of its operation and defining of a conceptual design for a probe prototype. The conceptual design will include all features and needs of the probe including its optimum geometry, the probe housing, packaged miniaturized optics, its operation, and its facility needs. In Phase II a prototype of the optical gas temperature probe will be fabricated, and its capability verified in the laboratory and in the field.

Anticipated Results/Potential Commercial Applications as described by the awardee: The research is expected to provide an accurate, reliable, and affordable optical gas temperature probe and monitoring system allowing direct measurement of high temperature process streams (>1500 K) currently not practical with state-of-the-art diagnostics. It would leave a substantial commercial market in both research applications and in industry. University, federal, and industrial laboratories require direct gas temperature measurements for research on burners or larger scale combustor and process gas streams. Large industrial facilities (powerplants, manufacturing) represent a market for the probe as a device for process monitoring and control.

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Pulverizer Modification for Pyrite Separation at the Power Plant--EXPORTech Company, Inc., P.O. Box 588, New Kensington, PA 15068-0588; (412) 337-4415
Dr. Robin R. Oder, Principal Investigator
Mrs. Marcia R. Oder, Business Official
DOE Grant No. DE-FG05-94ER81764
Amount: $74,977

In Phase I, a preliminary engineering design and cost estimate will be prepared for a one ton per hour (TPH) skid-mounted instrument-controlled coal cleaning pilot unit to be built and operated in Phase II. The pilot unit will consist of a modified air swept ring/roller pilot mill with attached magnetic separator. The unit is designed for separation of pyrites and other minerals from the internal circulating load of the roller mill when preparing minus 200 mesh coal for direct firing. The unit will be used in Phase II to demonstrate the efficiency of the ring/roller mill-magnetic separator combination in preparing low sulfur and low ash pulverized coal. The team will also prepare a conceptual estimate of the cost to build or to retrofit a commercial pre-combustion raw coal desulfurization unit consisting of a dry magnetic separator attached to and treating a portion of the high sulfur internal circulating load of a 50 TPH pulverizer producing 70%-80% minus 200 mesh clean coal.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project could lead to new mills for pulverization and desulfurization of direct fired coal at power plants, steel mills, or other industrial sites, as well as for direct-fired coal pulverizer retrofits and minerals beneficiation.

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Fluid Bed Combustor Compliance Coal Production--Grand Forks Activation Technologies, 120 North Washington Street, Grand Forks, ND 58203-3451; (701) 772-1733
Dr. Curtis L. Knudson, Principal Investigator
Dr. Curtis L. Knudson, Business Official
DOE Grant No. DE-FG02-94ER81773
Amount: $69,577

Many low rank coals (especially lignites) have only marginally high sulfur contents, resulting in emissions of 2 to 3 pounds of sulfur dioxide (SO_2) per million Btu. This sulfur is present in about equal amounts of pyritic, sulfatic, and organic sulfur. Therefore, physical cleaning methods are typically not applicable. However, these coals have high oxygen contents, and much of this oxygen is present in carboxylic acid functionalities that could provide sites for calcium ion exchange. Calcium could be incorporated into the coal structure, close to the sulfur, where it could efficiently trap sulfur during fluid bed combustion. Thus, the calcium-exchanged material would be combustible as a compliance coal, eliminating the need for mechanically intensive scrubbing or sorbent injection techniques. The ash content of the coal may be somewhat higher, but the total plant solids would be less and solids handling would be simpler. In Phase I, the method of ion exchanging coal with calcium in a simulated stockpile will be investigated, as well as the performance of the product in a small fluid bed combustor (FBC).

Anticipated Results / Potential Commercial Applications as described by the awardee: Demonstration of the economic production of compliance FBC fuels from moderately high sulfur coals should increase their marketablility. Capital and operating costs of FBCs would be lower, encouraging their usage. This would be environmentally beneficial, since FBC nitrogen oxide emission levels are normally within EPA compliance limits. Phase II of this effort will integrate coal company and FBC vendor participation in pilot-scale testing of the SO_2 control method.

55

A Low Nitrogen Oxide High Performance Power Systems (HIPPS) Coal/Gas Burner-- Johanson and Associates, Angwen Avenue, Route 7, Box 7336, Manchester, TN 37355; (615) 728-3229
Mr. Norman R. Johanson, Principal Investigator
Mr. Norman R. Johanson, Business Official
DOE Grant No. DE-FG05-94ER81794
Amount: $74,935

This project will investigate an innovative burner for the control of oxides of nitrogen (NO_x) from the combustion of fossil fuel, i.e., coal and natural gas, and in the future extend to 100 percent coal to meet or exceed the requirements of the High Performance Power System (HIPPS). The HIPPS is a combined cycle power plant consisting of an indirectly fired Brayton topping cycle and a conventional Rankine bottoming cycle with goals of an overall efficiency of 47 percent and NO_x levels at or below 0.15 lb/MMBtu (=100 ppm). The goal of Phase I is to test an advanced primary combustor developed at the University of Tennessee Space Institute and configured with internal natural gas reburning which in concept could be used in the High Temperature Advanced Furnace in the HIPPS program as well as a replacement for conventional wall-mounted burners in pulverized-coal fired utility boilers. Additionally in Phase I, the combustor will be scaled up from the current 6 MMBtu/hr to a 25 MMBtu/hr furnace-wall-mounted configuration and tested during Phase II, in a 25 to 50 MMBtu/hr test facility. A previous short term test using this combustor configuration has produced NO_x emissions with coal firing that were slightly below 0.3 lb/MMBtu when propane reburning supplied 14% of the total Btu input. By testing in Phase I with lower primary stoichiometry and increased reburning rate, it may be possible to achieve NO_x emissions of 0.15 lb/MMBtu or lower with propane or natural gas reburning supply equal to 35% of the total Btu input. During testing of this combustor 99.3% carbon conversion was achieved in long term 100% coal firing tests. The burner-replacement which will be scaled up to a 100 MMBtu/hr commercial configuration by the end of Phase II, represents an advanced concept with the potential for ultra-low NO_x in a furnace-wall-mounted configuration.

Anticipated Results / Potential Commercial Applications as described by the awardee: The anticipated result of this project will be that the existing data can be extrapolated to the HIPPS NO_x requirements of 0.15 lbs/MMBtu/hr using 65 percent pulverized coal and 35 percent natural gas. Application to retrofit existing fossil steam generation plants can be realized should the results be positive.

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Low Cost Synthesis of Nanocrystalline Silicon Carbide Starting with Fullerene Precursors--
Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706; (602) 574-1980
Dr. S. Guha, Principal Investigator
Dr. R. O. Loutfy, Business Official
DOE Grant No. DE-FG02-94ER81803
Amount: $75,000

A novel technique for the synthesis of nanocrystalline silicon carbide (SiC) powders is planned starting with a silicon-based precursor and fullerene compounds as the raw materials. The reactivity of fullerenes, combined with previously demonstrated results in the synthesis of limited quantities of such noncrystalline SiC powders using a spark erosion technique, form the basis of this concept. Such processing will be carried out under a liquid solvent envelope thereby preventing exposure of the highly reactive SiC powder surfaces to the ambient atmosphere. Such nanocrystalline SiC powder with good purity is expected to exhibit excellent low temperature sintering characteristics which will lead to fully dense SiC components obtainable even with low temperature processing. The Phase I project will involve demonstrating feasibility of producing commercially significant quantities of nanocrystalline SiC and characterizing their microstructure and sinterability characteristics.

Anticipated Results/Potential Commercial Applications as described by the awardee: Nanocrystalline SiC powders with low impurity content and good sintering characteristics would find applications in engine components for both aerospace and automobile engines. Further, this technology, if demonstrated feasible, could be easily extended to the synthesis of nanocrystalline tungsten carbide and other carbide powders.

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Energy Reduction in Ball Mill Grinding--
Mountain States R&D International, Inc., and Arentzen Associates, Joint Venture, P.O. Box 310, Vail, AZ 85641; (602) 624-7990
Mr. Charles Arentzen, Principal Investigator
Dr. Roshan B. Bhappu, Business Official
DOE Grant No. DE-FG05-94ER81816
Amount: $37,190

Comminution of minerals by ball milling is energy intensive. Energy efficiency of ball milling ranges from less than 1 percent to 10 percent. Breakage by crushing is higher in efficiency but is impractical for production of a fine meshed product. It has been established in laboratory tests that high velocity impact breakage of particles results in complete breakage whereas low velocity impacts of the same kinetic energy result in reduced or no breakage. Since shattered particles from impact breakage fly out of the impact zone, excessive impact energy will be wasted. In Phase I a series of laboratory single particle breakage tests on hard coal will evaluate kinetic energy required to break particles completely at each impact. Based on particle breakage efficiency, a coal feed size and make up media size will be calculated. Batch mill tests will be made in a standard mill and with a modification to the mill. By modifying the mill, a control of impact energy can be effected and the process intensified. Comparative energy consumption versus grind will define energy savings and provide data for Phase II continuous pilot plant testing.

Anticipated Results/Potential Commercial Applications as described by the awardee: Over 25 percent reduction of energy in coal grinding is anticipated by the proposed method. Additional benefits such as compressed grind, reduced media consumption, and fewer slimes will result. The technique has application to new and presently installed autogenous and semi-autogenous ball and pebble mills. World wide use for ore, cement, and stone processing will result in major savings in energy. Reduced milling costs will lower the cost of coal slurry for beneficiation, transport, and direct firing.

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Flame Monitoring and Optimization of Coal-Fired Burners Based on Frequency Spectra Analysis--PSI PowerServe, 20 New England Business Center, Andover, MA 01810-1077; (508) 689-0003
Dr. Mark J. Khesin, Principal Investigator
Mr. Stephen A. Johnson, Business Official
DOE Grant No. DE-FG02-94ER81835
Amount: $75,000

This project will explore the development of a new method for characterizing and optimizing performance of coal burners, by analyzing frequency spectra of coal flames obtained from the existing flame scanners. Most industrial and utility boilers are presently equipped with flame monitoring devices (flame scanners) for individual burners. The sole function of these scanners is to detect the presence of flame for burner management systems. The input to a flame scanner (flame signal) consists of two components, intensity and temporal fluctuations; one or both of these components can be used for flame detection. Over the years, numerous data and observations have been accumulated suggesting that the temporal frequency component of the flame signal (often called "flame signature") can be utilized to develop a powerful diagnostic tool to characterize flame performance. The overall objective of this project is to improve the performance of conventional and advanced combustors by relating flame frequency signatures of individual burner flames to flame stability, efficiency, and emissions. This innovation will allow NO_x emissions and optimize operation of individual burners. In Phase I, a new algorithm will be developed and tested for processing flame frequency spectra from conventional flame scanners for coal-fired, low-NO_x burners. This new algorithm will be based on computer processing of relative amplitudes of temporal spectra at different frequency bands. The algorithm is expected to show strong correlation with flame characteristics and could be used to evaluate flame stability, fuel-to-air ratio, unburned combustibles, and NO_x emissions. In Phase II the results will be tested on a large scale at several industrial and utility boilers equipped with different types of burners. The results will be commercialized in the form of new products (software packages and new flame monitoring systems).

Anticipated Results/Potential Commercial Applications as described by the awardee: A new algorithm is formed from the existing burner flame scanner signals and based on a computer processing technique. The algorithm will use flame signatures to characterize the performance of individual burners. It will add a new diagnostic and optimization tool to fossil power plants, particularly to coal-fired units equipped with low-NO_x burners.

59

Development of an Innovative, Low Cost, Continuous Process for the Production of Nanoscale Silicon Carbide--PSI Technology Company, 20 New England Business Center, Andover, MA 01810-1077; (508) 689-0003
Dr. Joseph J. Helble, Principal Investigator
Dr. Anthony N. Pirri, Business Official
DOE Grant No. DE-FG02-94ER81836
Amount: $75,000

Advanced electric power generation systems that are under development must generate high gas temperatures to improve cycle efficiencies and minimize effects on the environment. These high temperatures will require the use of ceramic materials in all or part of the system. Silicon carbide (SiC) is the ceramic best suited to meet this need. However, large grain sizes in commercial SiC materials make component fabrication costly and energy intensive. By reducing the grains to the nanoscale (10^{-9} meter) range, more cost effective and flexible processing may become feasible. In Phase I, a novel, high temperature, continuous aerosol method for producing nanoscale SiC powders in a flow reactor will be investigated. By spraying a reactive mixture into a high temperature environment, it is believed that nanoscale SiC can be produced without agglomeration or contamination. Phase I will focus on the production of nanoscale SiC powder using inexpensive precursors to demonstrate process feasibility. In Phase II, large quantities of SiC will be produced. Detailed sintering and mechanical properties testing will then be conducted to demonstrate the improved performance associated with nanoscale SiC.

Anticipated Results/Potential Commercial Applications as described by the awardee: A low cost process for the production of nanoscale SiC would have broad applications. Currently, conventional micrometer-grained SiC is being used or considered for wear parts, cutting tools, high temperature engine components, abrasives, and structural materials. Improvements in material strength and reductions in sintering energy requirements made possible by the use of nanoscale grains should greatly increase the use of this material.

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Fullerene Based Catalysts for Heavy Oil Upgrading--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033; (303) 940-2301
Dr. William L. Bell, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-94ER81879
Amount: $75,000

Heavy oils, including residues from crude oil distillation (resids), represent an abundant energy resource that is not fully utilized. It has been estimated that if only 20% of these crudes could be recovered, they would produce 1.27 million barrels of oil per day for the next 25 years. Use of heavy oils requires catalytic hydrogenation for removal of sulfur and nitrogen, and to lower the boiling range. Improved catalysts for heavy oil upgrading are highly desirable, and a promising area for improvement is the use of carbon catalyst supports, which show enhanced activity over traditional alumina supports. The recent discovery of fullerene carbon now offers the potential for preparation of improved carbon-supported catalysts. Fullerene-based catalysts in which nanoscale metal particles are deposited onto a carbon soot produced in conjunction with fullerene carbon will be investigated. This soot has been shown to possess remarkable properties that should be ideal for the hydroprocessing of heavy oils and resids. In Phase I the fullerene-based catalysts will be prepared, and screening tests with model systems will be conducted to identify effective catalysts. Phase I research will also test the best candidate catalysts with authentic samples of heavy oils and compare the results with catalysts currently in use. It will include an engineering analysis to determine the cost-effectiveness of the new catalysts. Phase II will systematically investigate the fullerene-based catalysts to achieve high performance, followed by commercialization in Phase III.

Anticipated Results / Potential Commercial Applications as described by the awardee: A successful project will lead to improved fullerene-based catalysts for use in heavy oil upgrading, as well as other possible applications. Improved catalysts for the intended application will lower the cost of converting heavy oils to more valuable materials.

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A Coal On-Line Process Control Analyzer--Tri-Valley Research, 3590 Churchill Court, Pleasanton, CA 94588; (510) 846-6991
Dr. Robert M. Pearson, Principal Investigator
Mr. Paul Anderson, Business Official
DOE Grant No. DE-FG03-94ER81893
Amount: $74,750

An analytical instrument capable of selecting coal blends that meet fuel and sulfur dioxide requirements with minimum post combustion emissions will be assembled and demonstrated in Phase I. The analyzer will use nuclear magnetic resonance to measure the carbon, hydrogen, and the moisture contents of coal and x-ray fluorescence to measure its ash and sulfur contents. This approach to coal evaluation recognizes that a complete elemental analysis is not necessary for the calculation of heat value and environmental impact of coals as they are used by most utility boilers. A reliable moisture analysis is essential in the evaluation of a coal's utility. A nuclear magnetic resonance spectrometer can quantitatively measure the various types of water found in coal plus the concentration of hydrogen bound to carbon atoms. Those measurements together with the determination of ash and sulfur by x-ray fluorescence spectrometry allow the selection of coal blends that best meet the emissions and fuel requirements of utility boilers. The combined spectrometer can be configured either as a small, relatively inexpensive laboratory device to measure individual samples sequentially, or as an on-line dynamic process control analyzer to characterize coal streams of any size.

Anticipated Results / Potential Commercial Applications as described by the awardee: This coal analyzer will be designed for operation by plant operators either on-line in the field, or in a laboratory. It will provide low cost real-time measurements to characterize coal at mines, transfer stations, gasification or liquefaction plants, blending facilities to select coal blends which will meet emission standards when burned, or at utility boilers for combustion optimization.

ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY FOR FOSSIL ENERGY

62

Controlling Mercury and Selenium Emissions from Coal-Fired Combustors Using a Novel Regenerable Natural Product--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Mr. Richard J. Schlager, Principal Investigator
Dr. Michael D. Durham, Business Official
DOE Grant No. DE-FG02-94ER81692
Amount: $74,984

Fossil fuel combustion sources are the largest single contributor of atmospheric mercury emissions and the second largest contributor of atmospheric selenium. Of all the trace metals contained in coal, mercury and selenium are of greatest concern since they are the most volatile of the metals, they are widespread and relatively toxic, and they deposit in biosystems. In anticipation of future emissions regulations, there is a need to develop measures that will control these specific metals. These metals are difficult to collect because of unusual chemical and physical properties. Although selenium is removed in various degrees by flue gas desulfurization systems, control systems are not designed specifically to control selenium. Existing mercury control systems rely on the use of sorbents or wet-scrubbing equipment. In addition, once the mercury is captured, these sorbents may become hazardous wastes that must be disposed of. Furthermore, control systems do not provide consistent removal efficiencies for mercury. Therefore, a unique naturally-occurring sorbent to capture mercury and selenium will be developed in Phase I. A significant benefit of the sorbent is its regenerability, which allows the adsorbed metals to be recovered for re-use and eliminates the generation of hazardous wastes. Process economics are expected to be favorable since the sorbent is a re-cycled natural product, it can be regenerated for re-use, and the adsorbed metals can be recovered.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful development of the proposed sorbent will provide coal-fired combustors with a single package that will effectively remove selenium and mercury from flue gas streams. Solid waste volumes associated with existing control technologies will virtually be eliminated using the proposed sorbent. Critical technical and economic issues will be addressed during Phase I, and scaled-up field tests are planned for Phase II.

63

Improved Hot Stream Cleanup Using an In-Situ Multi-Gas Monitor--Advanced Fuel Research and On-Line Technologies Inc., 87 Church Street, P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. Peter R. Solomon, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG05-94ER81694
Amount: $74,983

Removal of contaminants from hot gas streams fed to downstream equipment is essential to successful development of advanced coal utilization and conversion processes. The operation and optimization of such removal process often requires diagnostic instrumentation to measure concentrations and temperatures of contaminant species. One objective is the development of an in-situ methods for simultaneously measuring NO, N_2O, NO_2, NH_3, CO, SO_2, CO_3, HCL, and air toxics. The in-situ sensor will employ a state-of-the-art Fourier Transform Infrared (FT-IR) process spectrometer. Robust software is being developed for this system for gas quantitative analysis, even in the presence of high H_2O concentrations. To create an in-situ probe, the FT-IR sensor will be coupled to a porous ceramic diffusion cell. This cell is inserted into the hot gas stream and because of the diffusion through the porous wall driven by the gas velocity, the cell maintains a gas concentration equal to that in the outer stream without particulates. The application of this technology will be developed and demonstrated by controlling a Selective Non-Catalytic Reduction (SNCR) for the control of NO_x and NH_3 (which is an unwanted by-product). The objective of Phase I is to design, build, and test a prototype system which couples the FT-IR sensor with the porous in-situ diffusion cell to provide inputs to a commercial process. After laboratory testing and calibration of the sensor, a field test will be performed in a pilot plant which has extensive monitoring facilities.

Anticipated Results/Potential Commercial Applications as described by the awardee: The technology will be ideally timed to meet a large and growing requirement in industry for analytical instruments to monitor process streams, effluent pollution and ambient air quality. There are many applications where the ability to measure multiple parameters with a single instrument give FT spectroscopy a significant advantage. Specific applications of a multi-gas monitor which can measure ammonia are for SNCR processes for NO_x control, monitoring NH_3 in coke production facilities, and monitoring of NH_3 and other gases in chemical production facilities. There are also important applications in monitoring of air toxics and any other species.

64

An Optical Technique for Non-Intrusive Characterization of Fine Particulates in Flue Gas Streams--Aerometrics, Inc., 550 Del Rey Avenue, Sunnyvale, CA 94086; (408) 738-6688
Dr. William D. Bachalo, Principal Investigator
Dr. William D. Bachalo, Business Official
DOE Grant No. DE-FG03-94ER81699
Amount: $74,694

The feasibility of using a novel light scattering intensity ratio technique for the simultaneous measurements of the speed and size of non-spherical particles will be examined in Phase I. The technique makes use of two concentric laser beams with different diameters and the amplitude of the signals from the light scattered by the particles traveling through the probe volume to infer their size and speed. The sizing of irregular particles is accomplished by using near forward collection of the scattered light, in which depolarization of the scattered light by irregular particles is not significant, and the scattered light intensity is only sensitive to the projected area of the particles. The planned technique will have the ability to (1) size both spherical and non-spherical particles, (2) measure the particle number density and volume flux, and (3) measure the particle speed. The objectives of Phase I are to: (1) investigate the feasibility of using this novel technique for non-spherical particle size measurements, (2) conduct calibration measurements of spherical and non-spherical particles, and (3) study the feasibility of using laser diode technologies for compact probe development.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned laser diagnostic technique for particle sizing has a wide range of applications in practical environments. It can be used for the diagnostics of spherical and non-spherical particles present in flue gas streams, coal-water slurries, soot conglomerates, fly ash, and combustion generated particles. There is presently no single instrument which can successfully be used for measuring particles in such a wide range of industrial applications.

65

A Ceramic Material and Process for Use in Monolithic Ceramic Cross-Flow Filters--Blasch Precision Ceramics, 99 Cordell Road, Schenectady, NY 12304; (518) 372-9416
Mr. David A. Larsen, Principal Investigator
Mr. David W. Bobrek, Business Official
DOE Grant No. DE-FG02-94ER81718
Amount: $74,937

Ceramic cross-flow filters have been designed to provide high temperature, high pressure removal of particulates from hot gas streams in coal fueled power systems, with the benefit of high surface area per unit volume. However, further ceramic technology is needed on cross-flow filters to improve both effectiveness and reliability. An important need has been identified as a one-piece monolithic ceramic cross-flow filter, rather than the present segmented filter that has been known to delaminate in service.

This delamination allows particulates to bypass the filter, which could lead to costly damage to downstream turbines and subsequent failure to meet environmental regulations pertaining to stack gas emissions. Current ceramic technology has proved incapable of forming a complex one-piece shape of this nature with an acceptable permeable, porous ceramic material. A unique and proprietary injection mold ceramic forming process has been used for years to produce complex one piece monolithic shapes commercially, but of a non-permeable nature. The development of a permeable ceramic composition for this process represents a significant effort. In Phase I, the aim is to demonstrate the feasibility of a novel technology where a permeable, porous ceramic material is formed with this process, targeted to meet the filtration and environmental requirements of cross-flow filters. With this material and process, a much more reliable, effective monolithic ceramic cross-flow filter can evolve.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase I results are expected to show which of several ceramic composition variations produce favorable permeability and hot strength properties suitable for cross-flow filter application. The Phase II objective will be prototype production and field testing of monolithic ceramic cross-flow filters to demonstrate a new level of effective, reliable removal of particulates in hot gas streams, in coal fired power systems. The new filter design is expected to significantly reduce stack emissions and reduce costly downstream turbine damage and downtime in coal-fired power systems.

66

A Mercury Compound Luminescence Determination Method and Apparatus--Brooks Rand, Ltd., 3950 Sixth Avenue, Northwest, Seattle, WA 98107; (206) 632-6206
Dr. Craig W. Brown, Principal Investigator
Mr. Richard J. Brooks, Business Official
DOE Grant No. DE-FG03-94ER81719
Amount: $60,217

This project investigates the molecular electronic spectra of mercury compounds suspected to be present in coal fired power plant flue gas. These compounds include mercuric chloride, dimethyl mercury, and monomethyl mercuric salts (methyl mercury). Methyl mercury is particularly important because of its toxicity and propensity for bioaccumulation. Prior chemical methods indicated its presence in flue gas, but are known to be unreliable. This project seeks a reliable direct spectroscopic method of performing methyl mercury determinations in flue gases. The Phase I research emphasizes steady-state luminescence. In general, luminescence-based quantitation methods can be more sensitive than light absorption alone. In addition, time resolved methods can yield determinations even in the presence of interferences from compounds with overlapping spectra. The elegant time resolved methods cannot be used, however, unless the target compounds actually luminesce and the steady state luminescence is characterized. This characterization is the goal of this Phase I research. The results will indicate the feasibility of luminescence-based detection, and will set the stage for research and development to apply time resolved methods.

Anticipated Results/Potential Commercial Applications as described by the awardee: Potential commercial applications of anticipated results include mercury monitoring systems. In particular, a turn key system is targeted that will implement luminescence based quantitation of methyl mercury in flue gas. This system is intended to provide results in field conditions, and in near real time.

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An In-Situ Microanalysis of Coal Flyash: The Feasibility of Correlating Organic Surface Chemistry and Particle Composition--Charles Evans and Associates, 301 Chesapeake Drive, Redwood City, CA 94063; (415) 369-4567
Dr. Jang-Jung Lee, Principal Investigator
Mr. James E. Plank, Business Official
DOE Grant No. DE-FG03-94ER81725
Amount: $74,908

Coal flyash, one of the most widely studied types of pollutant particles, is a complex mixture which encompasses a broad range of particle compositions, sizes and morphologies. Organic compounds including polycyclic organic matter (POM) can adsorb onto these particles during coal combustion processes. Many of the POM compounds and their derivatives are known to be carcinogens or mutagens. The POM also may undergo reactions on particle surfaces to yield chemical products presenting greater health risks. The nature of the particle surface plays a critical role in these POM transformations. Particle-adsorbed POMs have been studied with solvent extraction analysis of large collections of flyash particles. However, significant heterogeneity among particles as well as more surface-specific chemistry may not be adequately detected with these techniques. In order to fully understand these surface chemistries, a detailed surface and bulk microanalysis of individual particles is needed. A unique time-of-flight secondary ion mass spectrometer (TOF-SIMS) will be used to evaluate the in-situ surface chemistry of coal flyash. Secondary ions characteristic of the near surface composition of the sample surface are produced by a low intensity, pulsed primary ion beam. This sensitive surface mass spectrometry technique provides the advantages of high mass resolution, large mass ranges, and high sensitivity for in-situ microanalysis of elements, organic and inorganic species. The high spatial resolution of TOF-SIMS ion imaging is essential for direct analysis of individual flyash particles. The emphasis of Phase I will be to determine the feasibility of correlating flyash surface composition and POM coverage and reactivity. This research will emphasize the study of particle surfaces, including the ability of these surfaces to concentrate and/or transform environmentally significant compounds such as POM. This feasibility study will also attempt to correlate particle surface characteristics with reaction processes such as POM photolysis or nitration.

Anticipated Results/Potential Commercial Applications as described by the awardee: The analytical protocols which would be developed as a result of this research could significantly facilitate future monitoring of the chemical composition of combustion-generated particles. These analytical methods could also provide sensitive and specific chemical analysis of various airborne particulates. The development of specialized organic microanalysis techniques for particulates could also lead to the development of specialized instrumentation for this type of characterization. This instrumentation would find markets in environmental clean-up and monitoring industries as well as ultraclean manufacturing industries such as semiconductor industry.

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Coal Ash Tiles by Microwave Processing--
Chemat Technology, Inc., 19365 Business Center Drive, Suite 8, Northridge, CA 91324; (818) 727-9786
Mr. Haixing Zheng, Principal Investigator
Mr. Patrick Lin, Business Official
DOE Grant No. DE-FG03-94ER81727
Amount: $75,000

This Phase I project considers the use of microwave heating for the production of tiles and bricks from coal-derived ash. The generation of undesirable ash from coal-fired power plants has become a serious environmental problem. Coal-fired power plants are responsible for the annual production of more than sixty million tons of ash in the United States. A typical 800 megawatt station consumes 7500 tons of coal and generates 1000 tons of bottom and fly ash daily. Ash contains heavy metals, and the disposal of this material in landfills is drawing increased attention. Much of this attention is warranted by the fact that ash is a finely divided oxide powder with a large surface area. Since the leaching of a constituent from a powder is proportional to its surface area, it would be desirable to design a method of consolidation involving surface area reduction. The interest in such a technique would be greatly increased if, in addition to volume and surface area reduction, the product had usefulness and commercial value. For example, tiles or bricks can be fabricated, but conventional methods of heating used in tile manufacturing require large flows of air which can cause air pollution. They are also time and energy consuming because it is relatively difficult to heat a powder. Microwave processing allows for low cost, volumetric, ultra-rapid, uniform heating without air pollution. Most types of ash absorb microwaves. However, if some do not, small amounts of a microwave coupler such as ferrous/ferric oxide may be added to form a microwave coupling mixture. Upon heating, the ashes will sinter and undergo a reduction in surface area. Under appropriate processing conditions, this would result in (1) the formation of a mechanically strong material shaped as a tile or brick, (2) encapsulation of heavy metals in a very stable glassy phase, and (3) elimination of the environmental issues associated with the starting material.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful development of this technology through Phases Iand II would result in a new product with two fold commercial potential: (1) elimination of the cost of transportation, landfilling, insurance, and potential lawsuits emerging from landfilling of coal residues, and(2) introduction of new types of tiles, bricks, and construction materials to the market. The potential commercial applications of the microwaved coal-ash tiles are tiles and bricks for construction, paving, roofing, decoration, artificial reefs, low permeability liners for landfills, and all other applications of ceramic tiles.

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Electrolytic Polymer Cells for Carbon Dioxide Conversion--Eltron Research, Inc., 2830 Wilderness Place #E, Boulder, CO 80301; (303) 440-8008
Dr. Anthony F. Sammells, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG02-94ER81749
Amount: $74,998

This project is directed towards the development of electrolytic polymer cell technology, incorporating advanced electrocatalysts recently identified for the direct electrochemical conversion of carbon dioxide (CO_2) to useful chemical feedstocks. CO_2 will be supplied to the electrolytic cell cathode compartment as a concentrated stream originating from advanced flue gas technologies. Specific CO_2 reduction products of interest are ethylene ethanol, and propanol. Electrocatalytic cells to be investigated will be based upon both proton and hydroxide ion conducting polymer electrolyte membranes. Electrocatalysts for CO_2 reduction will favor high coverage by an adsorbed carbon monoxide intermediate which will be expected to permit low overpotentials associated with subsequent electron transfer leading to the efficient synthesis of hydrocarbons and alcohols. There are clear incentives for development of this technology which will both lower costs associated with important chemical feedstocks and decouple dependency for their synthesis upon imported oil, based upon consumption of a greenhouse emission gas.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will result in characterizing an electrolytic technology compatible with the efficient and high rate conversion of carbon dioxide to commercial fuels and chemicals. Since these products are widely used and needed feedstock materials, this technology would be of significant economic and social benefit to the Nation by utilizing a significant greenhouse gas for their synthesis. This strategy will offset the cost of emissions control associated with advanced flue gas cleanup.

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Flue Gas Cleanup Using a Novel Corona Generator--Environmental Elements Corporation, 3700 Koppers Street, P.O. Box 1318, Baltimore, MD 21203; (410) 368-7239
Dr. Paul L. Feldman, Principal Investigator
Dr. Paul L. Feldman, Business Official
DOE Grant No. DE-FG05-94ER81761
Amount: $74,650

The Clean Air Act Amendments of 1990 will require more stringent control of emissions of gaseous contaminants such as sulfur oxides (SO_x), nitrogen oxides (NO_x), and the volatile air toxics. This trend toward more stringent air quality standards clashes with the demands of emerging markets: lower air pollution control equipment cost and higher collection efficiencies for these contaminants. This grant application is for the development of a superior method of applying corona chemistry. The Phase I project will study the effect of system variables such as geometry, residence time, type of energization, and polarity on pollutant removal efficiency and energy requirement. These results will indicate optimum conditions for which systems viability and economics can be determined for use as the basis for a decision to proceed to Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that a system based on this corona chemistry concept will be more economical than competitive systems for SO_x and NO_x control. It will be even more attractive if simultaneous control of volatile air toxics can also be demonstrated. The concept should find application in the industrial and utility power/combustion markets and in high temperature chemical processes such as petroleum refining, cement, glass, and metallurgical applications.

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Laminar Flow Electrostatic Precipitation--Environmental Elements Corporation, 3700 Koppers Street, P.O. Box 1318, Baltimore, MD 21203; (410) 368-7239
Dr. Paul L. Feldman, Principal Investigator
Dr. Paul L. Feldman, Business Official
DOE Grant No. DE-FG05-94ER81760
Amount: $74,965

Regulations governing the control of particulate emissions are becoming increasingly strict in terms of the control efficiencies they require. Several driving forces are responsible for this trend, foremost of which is the need to control toxic air emissions, such as trace metals and heavy organic compounds. Other driving forces include the Ambient Air Quality Regulations and state and local regulations for stack opacity. In each case, effective control translates to the high-efficiency removal of sub-micron particles. Unfortunately all particulate control devices are least efficient in the sub-micron region. High-efficiency control of particles in this region truly stresses the economic and reliability limits of conventional control equipment, and because 100% collection efficiency cannot be reached in conventional equipment, the cost of particulate removal increases rapidly as regulations force that level to be approached. What is needed is a device which is capable of 100% control, and laminar-flow electrostatic precipitation is known to have that capability. Although demonstrated in small-scale equipment, a practical design is needed which will allow laminar flow to be sustained on an industrial scale. Phase I will evaluate three options for exploiting laminar flow electrostatic precipitation as an ultra-high particulate collector in a practical and economic way.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that a wet laminar-flow precipitator design will be shown to be an effective and practical way to achieve total particulate control. Although widely applicable its greatest market potential should be in larger industrial and utility applications, such as power generation and waste incineration, as the best available means for high-efficiency control of fine particulate matter as will be required in the future.

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Simultaneous Hot Desulfurization and Improved Filtration in Coal Utilization Processes--Industrial Filter and Pump Manufacturing Company, Inc., 5900 Ogden Avenue, Cicero, IL 60650; (708) 656-7800
Mr. Paul Eggerstedt, Principal Investigator
Mr. Paul Eggerstedt, Business Official
DOE Grant No. DE-FG02-94ER81786
Amount: $75,000

Although this Nation has some of the greatest coal reserves in the world, many of them will remain unusable until technology is developed to meet both Clean Air Act mandates and New Source Performance Standards (NSPS) for particulate, sulfur dioxide (SO_2), and nitrous oxide emissions, effectively and economically. Recent breakthroughs in particulate control, specifically ceramic filtration technology, have shown that NSPS limits on particulates can be achieved at high process temperatures, thereby minimizing thermal losses and system complexity. Experimentation with sorbents, particularly metal oxide sorbents, has resulted in promising SO_2 emissions level reduction. Moreover, spent metal oxides, such as those generated by steel manufacturing and smelting processes, have shown promise as candidates in SO_2 removal, on a much more cost effective basis. For example, preliminary testing using spent iron oxide dust from a steel mill basic oxygen furnace (BOF) has shown that, in comparison to an equivalent volume of a more traditional sorbent such as calcium carbonate, BOF dust can remove approximately three times as much SO_2 before exhaustion. Because the affinity for SO_2 is probably not limited to spent iron oxide dust, Phase I will pursue the testing of several spent metal oxides to determine which show high affinity for SO_2 capture in a laboratory setting. The most promising candidates from Phase I would then be evaluated in the Phase II effort to verify their sorbent capacity by using thermogravimetric analysis and to determine their additional capability as high temperature filter aids, after classifying to a specific particle size distribution. Ultimately, when utilized as a "once-through" sorbent in a combination with ceramic filtration technology, these spent metal oxides would provide SO_2 removal and enhance filter performance in a most cost-effective manner.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase I results will show which spent metal oxides of those tested have the highest potential for SO_2 removal. The Phase II effort will show that these spent metal oxides can be of additional benefit as high temperature filter aids. By combining these sorbent and filter aid qualities with existing highly effective ceramic filtration technology, both particulate and SO_2 type emissions will be removed in a cost-effective manner. The availability of the spent metal oxides and the minimal processing required will allow this technology to be quickly developed and permit utility companies to utilize this Nation's high sulfur coal reserves while meeting existing emissions regulations.

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Optical Diagnostic Instrumentation for Use in Hot Gas Streams--M. L. Energia, Inc., P. O. Box 1468, Princeton, NJ 08542-1468; (609) 799-7970
Dr. Moshe Lavid, Principal Investigator
Ms. Nira Lavid, Business Official
DOE Grant No. DE-FG05-94ER81801
Amount: $75,000

A major obstacle to wider utilization of coal, tar sand, oil shale, and natural gas resources is environmental compliance. The employment of these abundant fuel resources is still fraught with the unacceptably copious emission of hazardous pollutants. In order to enforce compliance with emission control standards and to monitor the necessary clean up of hot and flue gas streams, a real-time, efficient, and reliable diagnostic system is needed. Current systems are expensive, delicate, and cumbersome. This project offers a novel optical diagnostic system capable of in-situ, real-time, and accurate monitoring of environmental pollutants. The main objective is to determine the feasibility of the planned system to accurately and in real time determine concentrations of polluting species generated by various combustion and chemical processes. This feasibility study encompasses the incorporation of readily available electro-optic components such as light source, fiber optics sensor, circular variable filter, Fabry-Perot interferometer, and infrared detector into an advanced novel instrument. The Phase I effort is directed into three main tasks: (1) evaluation of the trade-off between the various components to yield best overall performance, (2) design and construction of a breadboard prototype for a single representative species (e.g., a selected optical wavelength), and (3) overall integration and testing. Phase I will provide the technical basis for extending the diagnostics to other species during Phase II. Once feasibility is proven, a prototype will be designed, constructed, and fully tested.

Anticipated Results/Potential Commercial Applications as described by the awardee: The optical diagnostic system will have a broad range of commercial applications. It will assist the energy and chemical industries and, in particular, advanced coal-fueled systems to comply with environmental regulations by providing a real-time and affordable diagnostic system. It will be widely used by the environmental enforcing agencies, Federal, state, and local, and by research and testing laboratories. The system will be used to monitor flue gas emissions from conventional combustion and chemical processes. Finally, because of its portability and rapid employment, it will also be used for emergency monitoring of accidents involving discharge of pollutants to the environment.

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Development of Expansive Cements Using Dry Flue Gas Desulfurization Solid Wastes--Praxis Engineers, Inc., 852 North Hillview Drive, Milpitas, CA 95035; (408) 945-4282
Mr. Steven R. Hadley, Principal Investigator
Ms. Suzanne C. Shea, Business Official
DOE Grant No. DE-FG03-94ER81832
Amount: $74,992

Dry flue gas desulfurization (dFGD) is an emerging advanced sulfur dioxide (SO_2) control system for pulverized coal-fired power plants with an estimated 20,000-MW generating capacity worldwide. In this method, excessive amounts of calcium hydroxide are used to capture the SO_2 in the flue gas. The fly ash from these facilities differs from conventional pulverized coal fly ash in that it contains substantial amounts of sulfur compounds and unreacted calcium hydroxide in addition to the coal ash-derived fly ash.

The relatively high ratio of calcium hydroxide to fly ash is theoretically very promising since both are known to form pozzolanic reaction products similar to cement hydration, suggesting that the economics of using these fly ashes in blended cement would be more favorable than those for conventional fly ashes. However, this potential has not been realized to date because the proportion of sulfur compounds in the dFGD wastes is too high. The proposed research will investigate the potential for producing a special class of cements, termed expansive cements, using a high proportion of dFGD wastes blended with Portland cement and another specific additive. This additive is designed to react with the sulfur compounds in the dFGD ashes and result in a small controlled expansion of the concrete before it achieves a hardened state. This early expansion would compensate for the eventual drying shrinkage that occurs in all Portland cement concretes, thereby reducing the tensile stresses in the aged concrete that can lead to cracking. During Phase I, the effects of the fly ash composition (rank of coal from which it originated) and the ratio of the expansion additive to the sulfur concentration in the dFGD ashes will be investigated. Based on these tests, the preliminary economics of producing a dFGD expansive cement will be developed and marketing strategies formulated. If the results of Phase I are encouraging, a Phase II program will be developed to quantify the engineering properties of concretes produced from dFGD fly ashes and demonstrate that all specifications for expansive cements required by applicable ASTM standards are satisfied.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result of this project is development of the cement chemistry required to formulate expansive cements from dry flue gas desulfurization (dFGD) fly ashes. This technology will form the basis for production and marketing of blended expansive cements or cement additives using dFGD fly ash as a primary component. Three important benefits would result. First, the cost of landfill disposal of dFGD solid waste will be eliminated. Second, the energy cost for production of cement will be lowered because the addition of dFGD fly ash does not require the high-temperature processing and grinding used to produce conventional Portland cement. Third, the utilization of dFGD fly ash will reduce the mining requirements for cement kiln feed materials, thereby reducing the associated environmental impact.

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Toxic Materials Partitioning During Pulverized Coal Combustion: Measurement and Production--PSI PowerServe, 20 New England Business Center, Andover, MA 01810-1077; (508) 689-0003
Dr. Lawrence E. Bool, III, Principal Investigator
Mr. Stephen A. Johnson, Business Official
DOE Grant No. DE-FG02-94ER81834
Amount: $75,000

Of the 189 species designated as toxic air pollutants by the Clean Air Act Amendments (CAAA), 37, including 11 metals, are found in effluent streams of coal-fired power plants. Future regulations may require utility operators to carefully monitor and reduce emissions of these toxic metals. However, very little is known about the fundamental transformations of these metals in combustion systems. Current models to predict emissions are based on existing information on metal emissions and are of limited usefulness in exploring emissions of novel fuel blends and boiler configurations. This project will both obtain fundamental information on partitioning mechanisms for three trace metals and develop a directly marketable tool to predict partitioning of these metals in utility boilers. These metals include arsenic, selenium, and mercury. In Phase I combustion studies will be used to determine the governing mechanisms for partitioning of the specified metals. A commercial software package, based on these mechanisms, will be developed to predict metal partitioning in utility boilers.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will both expand the fundamental knowledge of metal transformations during coal combustion and lead to a software package to predict metal partitioning in utility boilers. This package, will allow utility operators to determine the effect of coal choices on trace metal emissions. Further, the project will help utilities determine if existing particulate control devices provide adequate emissions control, or whether alternative methods must be used.

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A Low Cost Method for Reducing Mercury Emissions in Fossil-Fuel Fired Power Plants--Reaction Engineering International, 77 West 200 South, Suite 210, Salt Lake City, UT 84101; (801) 364-6925
Dr. Warren D. Owens, Principal Investigator
Dr. Michael P. Heap, Business Official
DOE Grant No. DE-FG03-94ER81846
Amount: $74,997

Recently, there has been increased environmental concern about the emissions of mercury from combustion sources in the form of metal fumes or submicron particles. Naturally occurring mercury in a fuel vaporizes during combustion and then condenses as the combustion gases cool, leading to interesting challenges in the design and operation of equipment to clean the flue gases prior to stack release. Studies have indicated that mercury emissions can be reduced from coal fired power plants by injecting activated carbon or various sorbents. The drawback of these technologies is that they require considerable capital investment in equipment and material. The hypothesis that mercury emissions can be controlled using a low cost method of recycling fly ash from an air pollution device back into the flue gas stream without compromising the particulate emissions of the system will be explored. The approach used is based on both model/theoretical and experimental tasks. Process models and a pilot-scale coal fired facility will be used to answer this hypothesis in Phase I. Mercury adsorption behavior will be investigated using pulverized coal fly ash. The objective is to identify and quantify whether fly ash obtained from an air pollution control device can be recycled into the flue gas stream to control mercury emissions without compromising overall system performance and economics. More specifically, the knowledge generated in Phase I will be used to (1) identify how fly ash can be used most effectively to control mercury emissions from pulverized coal boilers, and (2) further define what tests are needed in a pilot/field demonstration for Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The results of this Phase I project will provide (1) the amount of residual fly ash carbon necessary for the control of mercury, (2) the governing mechanisms controlling the capture of mercury in flue gas, the adsorption capacities of fly ash, the effect of gas-phase species and entrained particle interactions, and the effect of the form of mercury on fly ash capture efficiency, (3) the suitability of a fly ash recycle stream to enhance mercury capture and provide additional control for the system, and (4) the combustion/facility parameters that can be modified to determine the economic trade-off in combustion efficiency versus mercury capture efficiency.

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Ultrasensitive In-Situ Detection of Toxic Flue Emission--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Allen Flusberg, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-94ER81855
Amount: $74,940

The 1990 Clean Air Act amendments list nearly two hundred toxic materials that must be regulated. Among these are polycyclic aromatic hydrocarbons (PAHs), carcinogens that are associated with incomplete combustion and fine particulates. There is therefore a need for new technology to measure very low concentrations of such species at sites adjacent to coal-fired utilities, which are sources of PAHs. Extractive methods, in which a sealed sample of air is analyzed in a laboratory, are expensive and are inapplicable to continuous, in-situ monitoring of the concentrations of these toxic emissions. This project will study the development of an instrument called a tunable pulsed absorption diffractometer (TPAD) to fill this need. The basis of this instrument is the detection of a transient, volumetric diffraction grating that is formed after a pulsed laser beam is absorbed by toxic emissions present in the illuminated region. An instrument that utilizes a tunable, pulsed infrared laser can be tuned through the near-infrared absorption spectrum of PAHs to determine their concentration in the presence of other absorptive species. A TPAD will be sensitive to a concentration of a part-per-trillion toxic gas concentrations, orders of magnitude better than instruments based on other approaches to detect such toxic species. The Phase I feasibility study will be followed by a proof-of-principle Phase II demonstration. The construction and testing of a prototype instrument will take place in Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: Once developed, the tunable pulsed, absorption diffractometer will be an essential tool for monitoring real-time, in-situ toxic PAH emission in the vicinity of coal-fired power plants, industrial sources of pollution, and heavy automobile traffic. Demand for these instruments will come from Federal, state, and local government agencies, as well as from the private sector.

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Development of an Electrochemical System for Carbon Dioxide Concentration--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033; (303) 940-2301
Dr. William L. Bell, Principal Investigator
Mr. Micheal E. Karpuk, Business Official
DOE Grant No. DE-FG03-94ER81883
Amount: $75,000

Control of carbon dioxide (CO_2) emissions from the combustion of fossil fuels may become necessary to minimize global warming produced by the greenhouse effect. Separation of CO_2 from flue gases will increase the efficiency and lower the cost of processes to fix CO_2 chemically or otherwise prevent its discharge into the atmosphere. Such a CO_2 transport system must operate at high efficiency to minimize the energy consumption and cost of reducing CO_2 emissions. This project will investigate a novel electrochemical system for the removal of CO_2 from the flue gas of coal-fired power plants. Previous work has demonstrated that electrochemical CO_2 separation systems can potentially operate at higher thermodynamic efficiency than others. A critical part of this system is a carrier molecule that can reversibly bind and release CO_2. The innovation is a class of water-soluble carriers for CO_2 transport and concentration. Phase I will prepare and test potential CO_2 carriers to identify those most effective in electrochemically transporting CO_2. Phase II will test the durability of the new carriers, and will design, construct, and test a prototype electrochemical process for CO_2 removal.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful project will develop a new system for CO_2 removal that can be used at fossil fuel burning power plants. This technology could lower the energy cost of minimizing CO_2 discharge. The system would be useful to the utilities that account for the majority of the Nation's electrical energy production, and has application in other areas where one component of a gas stream must be efficiently removed.

ADVANCED TECHNOLOGY FOR THE RECOVERY, STORAGE, AND UTILIZATION OF NATURAL GAS

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Landfill Gas Conversion to a Contaminant-Free Methane-Carbon Dioxide Reformer Feedstock for Methanol Synthesis--Acrion Technologies, Inc., 9099 Bank Street, Cleveland, OH 44125; (216) 573-1187
Dr. William R. Brown, Principal Investigator
Dr. William R. Brown, Business Official
DOE Grant No. DE-FG02-94ER81690
Amount: $74,979

Municipal landfills produce gas: several million standard cubic feet (SCF) per day from a modest landfill, and upwards to 5-10 million SCF/day from large landfills. Gas generation of this magnitude continues long after landfill closure, perhaps for 15 to 20 years. Landfill gas (LFG) is roughly an equal mix of methane (CH_4) and carbon dioxide (CO_2), which becomes contaminated with many volatile trace compounds as it migrates through the landfill. LFG collection systems are installed primarily to prevent off-site migration and control odors; reduction of greenhouse gas emissions is an indirect benefit. Most collected LFG is simply flared to convert CH_4 to CO_2, a non-explosive, non-toxic, less potent greenhouse gas. Economic and technical barriers discourage energy recovery from LFG. The cost of avoided power in many areas does not justify the conversion of LFG to electricity, while the technical difficulty of removing CO_2 and trace contaminants coupled with lack of natural gas pipeline access usually causes problems in the conversion of LFG to CH_4. Research is being conducted to further develop technology that converts raw LFG to a contaminant-free mixture of CH_4 and CO_2 to serve as reformer feedstock for methanol synthesis. No hazardous solvents or other separating agents are used; CO_2, an environmentally benign "green" solvent condensed directly from LFG, is used as cold liquid absorbent to remove LFG contaminants to below ppm levels. Temperature and pressure are selected to produce a contaminant-free mixture with the desired CH_4:CO_2 ratio for methanol synthesis, about 2.3:1. Methanol, easily stored and transported from a landfill, enjoys an expanding readily available market, and therefore could make LFG utilization profitable for relatively small landfills. The phase I objective is to demonstrate production of contaminant-free methanol synthesis feedstock gas from landfill gas by contaminant absorption with cold liquid CO_2. The amount of simulated LFG gas flowing to the liquid CO_2 absorption column will be about 30,000 to 40,000 SCF/day, a scale sufficient to demonstrate both technical and commercial viability to municipal landfill owners and operators.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful demonstration of LFG conversion to CH_4 synthesis feedstock will provide landfills with an attractive alternative to electricity or pipeline gas. Cold liquid CO_2 absorption of contaminants has wide applicability in gas processing beyond LFG treatment. Applications include acid gas removal from coal gasifier gas or from the partial oxidation of heavy hydrocarbons for the production of hydrogen or synthesis gas, acid gas removal from low quality natural gas, and Claus sulfur plant tail gas cleanup.

80

Metal Monoliths for Conversion of Natural Gas to Liquid Fuel--Alabama Cryogenic Engineering, Inc., P.O. Box 2470, Huntsville, AL 35804; (205) 536-8629
Dr. Michael L. Dingus, Principal Investigator
Ms. Mary T. Hendricks, Business Official
DOE Grant No. DE-FG05-94ER81701
Amount: $74,826

Advanced methods for the conversion of natural gas to liquid fuels are needed so that natural gas energy resources can be better utilized. In recent research breakthroughs, ceramic monoliths have been used in partial oxidation to catalyze very fast, high selectivity synthesis of higher hydrocarbons from methane. Use of metal monoliths (solid metal plates perforated with small, uniform holes) is planned as a new catalyst for carrying out these reactions. Metal monoliths have high thermal conductivity, so that the heat of reaction can be removed and the reaction temperature regulated. This will allow faster reactant feed rates and higher yields than are possible with currently available ceramic monolith catalysts. A novel fabrication technique allows thin layers of noble metals to be incorporated into the holes of the monolith, so that the reaction rate can be further enhanced. These monoliths can be fabricated with hole diameters less than one micron and porosities as high as 75%. The proposed metal monolith catalysts can be mounted in large arrays, and thus scaled up for commercial chemical production. In Phase I, metal monoliths will be used to examine the oxidation of CH_4 and other components in natural gas to produce synthesis gas and other liquid products. These reaction products can be used as fuels and in various chemical production processes.

Anticipated Results / Potential Commercial Applications as described by the awardee: The metal monolith catalyst technology provides a way to scale up laboratory oxidation reactions for commercial chemical production. Commercial applications include: (1) Replacement for steam reforming of natural gas in methanol synthesis; (2) Production of methanol and synthetic diesel fuels; (3) Generation of hydrogen in chemical plants; (4) Production of higher hydrocarbons to olefins and oxygenated products; (5) Generation of ethylene oxide from ethylene; (6) Production of acrylonitrile from propane; (7) Cleanup of flue gases; (8) Automotive catalytic converters; (9) Cleanup of waste gas streams.

81

A Membrane Reactor for the Spontaneous Conversion of Natural Gas and Carbon Dioxide Mixtures into Valuable Feedstock--Eltron Research, Inc., 2830 Wilderness Place #E, Boulder, CO 80301; (303) 440-8008
Dr. Michael Schwartz, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG02-94ER81748
Amount: $74,998

This Phase I project will be directed towards promoting the spontaneous conversion of methane/carbon dioxide mixtures into synthesis gas which will be available for subsequent conversion into methanol. This will be performed across novel mixed ionic (O^{2-}) and electronic conducting perovskite membranes over the temperature range of 600 to 800°C. Membranes will behave as short-circuited electrochemical cells. Compared to current methane steam reforming technology, which is endothermic and requires subsequent composition adjustment prior to the methanol synthesis step, the new technology would be both simple and inherently of low cost. Reformation of methane/carbon dioxide mixtures will rely upon O^{2-} species being continuously generated at an appropriately selected catalyst site on the oxidizing side of the membrane.

Anticipated Results/Potential Commercial Applications as described by the awardee: This research will result in characterizing a mixed conducting membrane technology compatible with the spontaneous conversion of methane/carbon dioxide mixtures to synthesis gas using oxygen conveniently separated from the atmosphere. This would be of significant economic and technical benefit to the Nation by lowering the cost of an important chemical feed stock using an inherently simple process.

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Tubular Catalytic Membrane Reactors for the Spontaneous Conversion of Humidified Natural Gas to Synthesis Gas--Eltron Research, Inc., 2830 Wilderness Place #E, Boulder, CO 80301; (303) 440-8008
Dr. Anthony F. Sammells, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG02-94ER81750
Amount: $74,993

This Phase I investigation is directed towards promoting the spontaneous conversion of humidified natural gas to synthesis gas compatible with subsequent preparation of methanol without any intermediate compositional adjustment being necessary. This will be performed across novel tubular mixed ionic (O^{2-}) and electronic conducting perovskite membranes over the temperature range of 600 to 800°C. Membranes will behave as short circuited electrochemical cells. Compared to current methane steam reforming technology, which is endothermic and requires subsequent composition adjustment prior to the methanol synthesis step, the new technology would be both simple and inherently of low cost. Initial methane activation will rely upon O^{2-} species being continuously generated at an appropriately selected catalyst site on the oxidizing side of the membrane.

Anticipated Results/Potential Commercial Applications as described by the awardee: This research will result in characterizing a tubular catalytic membrane reactor technology compatible with the spontaneous conversion of humidified methane to stoichiometric synthesis gas using oxygen conveniently separated from the atmosphere. This would be of significant economic and technical benefit to the Nation by lowering the cost of an important chemical feed stock using an inherently simple process.

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A Multi-Functional Component to Simplify Fuel Cell Power Plants--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 792-1460
Mr. Andrew Skok, Principal Investigator
Dr. H. C. Maru, Business Official
DOE Grant No. DE-FG05-94ER81756
Amount: $74,999

Carbonate fuel cell power plants offer the most efficient and environmentally superior option to generate electricity from natural gas, coal gas, and other hydrocarbon fuels. To realize the greatest commercial potential of these power plants, advances are desirable to improve the system performance and reduce its overall cost. This project addresses improvements in cost and performance characteristics of the carbonate fuel cell system. It replaces several subsystems by an integrated multi-functional component to reduce overall system cost. The proposed multi-functional system integrates the carbon dioxide (CO_2) management burner system with an oxidant recycle blower, an exhaust fuel booster, and start-up burners. The resulting system will have a minimum number of highly reliable components and a greater operating range. A cost savings of 100 to 150 $/kW may be realized with this approach. A techno-economic feasibility study is planned to investigate the attractiveness of the concept. During Phase I, a detailed parametric analysis will be performed for several discrete components. This will include the spent fuel burner used in CO_2 management, the hot oxidant recycle blower, and the start-up burner. Operability of these subsystems in an integrated mode using the planned concept will be examined. Experiments will be performed to verify the feasibility of parameters and integration options using a subscale test facility. During Phase II, a system verification of the multi-functional component in a carbonate fuel cell stack will be performed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned concept is anticipated to simplify a carbonate fuel cell power plant and improve its operability. A significant reduction of up to 100 to 150 $/kW in the system cost is anticipated. The carbonate fuel cell power plants, due to their outstanding thermal efficiency and environmentally superior characteristics, are expected to become a significant energy conversion option by the turn of the century. This concept will improve the commercial potential of carbonate fuel cell power plants, and offer an exceptional opportunity for providing economically competitive, high efficiency, low emissions power generators for utilities and industrial and commercial cogenerators. The concept, once developed, may also be used in solid oxide and phosphoric acid fuel cell power plants.

84

Cost Effective Stimulation of Shallow Gas Wells Using High Energy Gas Fracturing Fielded Without a Wireline or Workover Rig--J Integral Engineering, 165 Southwest Tualatin Loop, West Linn, OR 97068; (503) 557-1370
Dr. Richard A. Schmidt, Principal Investigator
Dr. Richard A. Schmidt, Business Official
DOE Grant No. DE-FG03-94ER81791
Amount: $74,832

Current models and data show that High Energy Gas Fracturing (HEGF) has great potential as a stimulation tool in shallow gas storage wells. In these wells the in situ stresses are sufficiently low for the process to generate adequate gas volumes and to create an effective multiple fracture network. To address this opportunity, HEGF fielding techniques must be simplified and costs reduced to provide a relatively low cost alternative treatment method that can restore deliverability without resorting to chemical treatment, hydraulic fracturing, or the drilling of new wells. The HEGF tool will be redesigned using a proprietary concept that will eliminate the need for wireline, slick line, tubing, or any other support equipment. It will also eliminate the problem of wireline damage so often experienced in HEGF treatments. Stimulation needs of shallow gas wells will be reviewed on technical and economic grounds to determine the degree of fracturing required in these wells. Existing HEGF models and data will be used to design a prototype treatment that meets these fracturing requirements. A single prototype treatment will be conducted with the new device in Phase I, and sufficient pre-test and post-test diagnostics and analyses will be conducted to provide inputs to the work plan for Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful design and testing of the improved HEGF device should lead to additional field tests in Phase II. Improved HEGF models, tested against a controlled data base, should optimize the process for shallow gas storage wells and improve the design of multiple fracture treatments in general. Phase III should commercialize the device and could provide the oil and gas industry with a new, cost effective stimulation technique.

85

Development of a Higher Pressure Rotary Blowout Preventer for Safe Directional Drilling in Underbalanced Applications--Kalsi Engineering, Inc., 745 Park Two Drive, Sugar Land, TX 77478; (713) 240-6500
Dr. M. S. Kalsi, Principal Investigator
Dr. M. S. Kalsi, Business Official
DOE Grant No. DE-FG03-94ER81796
Amount: $75,000

This project is aimed at the development of a new generation of rotary blowout preventers capable of safe, reliable, and cost effective handling of the high pressures expected in underbalanced horizontal and directional drilling applications. Pressures of up to 5,000 psi (or even higher) can be expected when drilling with air, foam, or nitrified mud in the low permeability formations in the U.S. (e.g., Greater Green River Basin) that have large amounts of recoverable natural gas. Attaining the goal of safely and economically recovering gas from these vast reservoirs by underbalanced drilling has been hampered by the lack of a suitable high pressure rotary shaft seal. Recent technological developments relating to a novel hydro-dynamically lubricated rotary shaft seal and a floating seal carrier have increased the pressure goal limits of rotary blowout preventers from 700 psi to 2,000 psi. To meet the high pressure goal of 5,000 psi, Phase I outlines a systematic technical development effort that includes a combination of innovative improvements, rigorous analysis, and testing of the high pressure rotary seal concept. Successful completion of Phases I and II will result in the development of an advanced technology 5,000 psi rotary preventer which has the potential of significantly reducing the cost of recovering natural gas in an environmentally acceptable, safe, and reliable manner.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of this project will result in an advanced technology high pressure and rotary blowout preventer. The new design will be capable of providing reliable, safe, and cost effective operation at pressures of up to 5,000 psi.

86

Membrane Module Development for a Natural Gas Dehydration Process--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025; (415) 328-2228
Dr. Hans Wijmans, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-94ER81807
Amount: $75,000

Virtually all natural gas must be dehydrated before entering the pipeline. Currently, glycol absorption dehydrators are widely used. However, these units coextract benzene, a known carcinogen, and release the benzene to the atmosphere. In addition, glycol dehydrators are not well suited for use on small gas streams or on offshore platforms, increasingly common sources of natural gas. Membrane processes are an alternative approach to natural gas dehydration. The costs are likely to be comparable to those of the glycol process for low throughput applications, but benzene emissions are eliminated. The suitability of the membrane process for use on isolated small gas streams and on offshore platforms is an advantage likely to encourage industry use. Membranes with the required selectivity and flux for a technically viable membrane dehydration process have already been identified. Small modules incorporating these membranes successfully dehydrate synthetic natural gas at pressures up to 950 psig. However, the membrane module design must be significantly improved to reduce or eliminate concentration polarization effects. Concentration polarization arises from the formation of a stagnant gas layer adjacent to the membrane, and decreases the module separation performance below acceptable levels. In Phase I, the module design will be optimized to mitigate the effects of concentration polarization and to maximize the separation achieved. In Phase II, the process will be scaled up to the pilot demonstration scale. A four-module pilot system will be constructed and equipped with commercial-scale modules. The ability of the system to dehydrate natural gas streams will be evaluated over a period of 3-6 months. Preliminary offers for Phase II field sites have been obtained from both a major gas field operator and a supplier of gas processing equipment.

Anticipated Results/Potential Commercial Applications as described by the awardee: A simple, efficient membrane process for the dehydration of natural gas would be competitive with conventional glycol and molecular sieve dehydration systems. The modular nature of membrane systems would make dehydration of small streams economically feasible. The absence of direct-fired reboilers and the reduced size and weight of the membrane systems are operational advantages, especially for off-shore gas production platforms.

87

Separation of Nitrogen from Natural Gas Using Novel Membranes and Membrane Processes--
Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025; (415) 328-2228
Dr. Kaaeid Lokhandwala, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-94ER81809
Amount: $75,000

Thirteen percent of known U.S. gas reserves, containing more than 4% nitrogen, cannot be exploited because no economical technology for removing the nitrogen exists. Membrane processes could make this gas available if membranes with a methane/nitrogen selectivity of 6 or more were available; A number of materials that are within the range of this selectivity have been developed. One polymer has a selectivity of 5.5, the highest polymer membrane methane/nitrogen selectivity known. These methane-permeable membranes will be incorporated into an innovative process that separates the raw gas into three streams: a product gas stream containing less than 4% nitrogen at pipeline pressure; a condensed, higher hydrocarbon (greater than 3 carbons) stream, which has more value as a liquid chemical feedstock than as a gaseous fuel; and a waste, nitrogen-rich gas stream, which is used to power the process and for other on-site fuel use. The cost of producing pipeline gas by the process is estimated to be $0.55/thousand standard cubic feet for a 1 million cubic feet per day plant, which is very competitive with alternative technologies. In the Phase I program, the new membrane materials will be evaluated, and the optimum material will be selected for scale-up in Phase II. The tests will provide data on the effect of temperature on the methane fluxes and methane/nitrogen selectivites. These data will then be used to perform a technical and economic feasibility analysis of a process that incorporates the membranes into an energy-efficient separation scheme that also recovers natural gas liquids. If the results are sufficiently encouraging, a skid-mounted proof-of-concept system will be constructed in Phase II for evaluation in the laboratory and in a small-scale field test.

Anticipated Results/Potential Commercial Applications as described by the awardee: If successfully developed, this process would allow low-quality natural gas from several large known, but currently unexploited, fields to be processed economically to pipeline specifications.

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Continuous Pressure Swing Adsorption (CPSA) for Nitrogen Rejection from Natural Gas--
Northwest Fuel Development, Inc., 4064 Orchard Drive, Lake Oswego, OR 97035; (503) 699-9836
Dr. Peet M. Soot, Principal Investigator
Dr. Peet M. Soot, Business Official
DOE Grant No. DE-FG03-94ER81819
Amount: $75,000

A continuous pressure swing adsorption (CPSA) process will be developed in Phase I for nitrogen rejection from low quality natural gas. This process will remove the sole techno-economic hurdle for utilizing major resources of low quality natural gas. This will provide a methodology for producing a valuable fuel resource out of gas resources which are currently either being thrown away or are left unused in the geologic formations in which they were discovered. The CPSA process takes the batch operating conditions of traditional PSA and yields a continuous system. The reduction of vessels and simplification of process operation yield significant economic advantages over batch PSA. The planned research should lead to the identification of process parameters which will be the basis for patent submittals. The fundamental concept of continuous rapid cycling PSA has been proven in the laboratory for different product objectives. This CPSA research can build on prior work to rapidly develop a commercial nitrogen rejection process.

Anticipated Results/Potential Commercial Applications as described by the awardee: A significant fraction of the Nation's gas reserves are of low quality. This is a resource of over 100 trillion cubic feet of natural gas. It could solely provide the entire Nation's domestic natural gas production for up to 10 years. This nitrogen rejection process also provides economic and environmental benefits. It is economically competitive, and it will capture and use the methane (a greenhouse gas) emissions which are now going into the air from coal mines.

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Forecasting Reservoir Thickness with Fractals--NW Resources, P.O. Box 187, Socorro, NM 87801; (505) 835-5220
Mr. Trent Boneau, Principal Investigator
Mr. Bill Weiss, Business Official
DOE Grant No. DE-FG05-94ER81821
Amount: $75,000

The Nation desires to expand the use of clean burning, competitively priced natural gas. The increased demand for natural gas has prompted new drilling in established gas fields. The proper placement of the new wells is dependent on the gas formation properties between the existing wells. One of the properties is the thickness of the gas bearing zone. It is generally accepted that the formation thickness between wells in natural gas reservoirs can be satisfactorily estimated with current technology. Unfortunately, current methods of estimating thickness such as isopach maps based on experience, judgement, and intuition have proven ineffective in predicting the formation thickness encountered by infill wells drilled in a gas reservoir. The infill wells were drilled in a one township area which encompassed 115 prior wells. Six wells cut a cumulative of 187 feet of gas producing formation where 320 feet were anticipated. The 200-acre well spacing did not provide the small scale information required to accurately estimate the interwell thickness. Fractal geometry is a new mathematical tool that has application in solving the small scale data problem. Fractals are based on the recurring nature of natural systems at various scales. The fractal properties determined from the large scale, areal variation in thickness measured at the existing wells will be used to predict the interwell (small scale) thickness at the infill drill sites. The objective of Phase I is to develop a predictive tool, based on fractal geometry, that will generate estimates of interwell thickness. The actual thickness measured at the existing wells in the reservoir will be a condition of the fractal estimates.

Anticipated Results/Potential Commercial Applications as described by the awardee: The completed research will be especially useful to petroleum technicians charged with expanding production from natural gas fields. The planned method, using field data other than thickness, could be used to predict the areal distribution of permeability, porosity, fractures, and faults. A successful conclusion of the research would be commercial software that can be used to improve the selection of infill drilling locations in heterogeneous natural gas fields.

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Redesign of Ammonia Absorption Refrigeration Units for Low Temperature Applications in Natural Gas Processing--Process Technology, Inc., 14811 St. Mary's Lane, Suite 165, Houston, TX 77079; (713) 493-4116
Mr. Jack Wiewall, Principal Investigator
Mr. J. R. Wiewall, Business Official
DOE Grant No. DE-FG05-94ER81833
Amount: $75,000

Gas transmission pipelines require natural gas delivered to them to meet a hydrocarbon (HC) dewpoint specification in order that the HC liquids are not dropped out in the line during transmission. Similar specifications are imposed by plant operators on the fuel gas that is consumed by their machinery. A market exists for an economical ammonia (NH_3) absorption unit to replace compression units utilizing freon that will produce refrigeration at temperatures in the range of -10° to -15° F. Existing commercially available air cooled NH_3 absorption refrigeration units are designed and manufactured to produce refrigeration in the 40 to 44°F range with ambient air temperatures ranging from 20 to 100°F. The NH_3 units are sealed units utilizing simple low cost mechanical devices to regulate the process flow. To extend the temperature range down to -15°F utilizing simple low cost controls will require some innovative control technology, component modification, and testing under varying load and ambient conditions. A test unit now operates at 20°F. The next step will require different controls and redesign of the unit components to achieve the lower temperatures. The objective of Phase I is to build testing facilities, provide a sophisticated variable control and monitoring system, do a detailed evaluation of the components in the unit, and do a preliminary evaluation of a new, low cost control system.

Anticipated Results/Potential Commercial Applications as described by the awardee: A low temperature unit would serve a market that currently exists for trouble free, low temperature chillers to chill natural gas to -15°F. This would a) allow production of good lean fuel gas, b) process small volumes of natural gas to produce liquid petroleum gases in older fields, c) replace compression units using freon and d) meet transmission line HC dewpoint specifications.

91

Systematic Mapping of Natural Fractures to Predict Coalbed Methane Production--Sage Discovery, Inc., 345 Market Street, P.O. Box 882, Meeker, CO 81641-0882; (303) 878-5160
Mr. Bruce E. Barnum, Principal Investigator
Ms. Jackie R. Barnum, Business Official
DOE Grant No. DE-FG03-94ER81851
Amount: $75,000

Reliable mapping of natural fracture systems existing in coal beds is the key to efficient development of the large volume coalbed methane resources in-place in the Piceance Basin located in northwest Colorado. Adequate permeability to support commercial production requires the presence of a well developed coal cleat system. In Phase I innovative evaluation methodology will integrate detailed direct coal cleat measurements, indirect indicators of cleat intensity, and geophysical interpretations with trend control from area structure and stratigraphy to produce maps delineating the pattern of coal cleat intensity and orientation. Distribution and relative importance of local reservoir permeability heterogeneities will also be evaluated. The study area on the north margin of the Piceance Basin includes approximately 25 recently completed coalbed methane wells which will provide production data to directly test and calibrate the maps for prediction of coalbed methane recoverability. If testing proves the utility of this recoverability evaluation, a significant level of true innovation will be achieved. New technology will provide knowledge essential for efficient recovery of this desirable resource, opening new opportunities for extensive resource development, and defining significant new U.S. clean energy reserves.

Anticipated Results/Potential Commercial Applications as described by the awardee: This evaluation is expected to produce maps rapidly and cost-effectively which provide a guide to efficient development of this important resource which is presently unavailable. Systematic application of this technology in Phases II and III to larger areas and other U.S. coal fields can be expected to result in significant profit opportunities for gas producers and new clean, domestic energy supplies.

92

Removal of Hydrogen Sulfide from Natural Gas by Electron Beam Irradiation--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Henry Eppich, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-94ER81853
Amount: $74,972

Natural gas represents 20% of the primary energy resources of the United States and accounts for almost half the energy consumed for residential heating. 22% of the natural gas reserves in this Nation are not usable because they contain more than 4 ppm of hydrogen sulfide (H_2S). This corresponds to 19 trillion cubic feet of the known reserves. It is projected that 80 trillion cubic feet of the undiscovered natural gas resources are also contaminated with unacceptable concentrations of H_2S. Natural gas contaminated with H_2S is an environmental hazard due to the toxicity of H_2S in the gas itself and the sulfur-containing compounds produced and released during combustion. In addition, it is corrosive to pipeline systems. Current technologies for H_2S removal are complex and cost between 20 and 26 cents per million standard cubic feet. This cost is independent of the concentration of H_2S. The cost of the electron beam process, based on all-solid-state accelerators, is 6 cents per million standard cubic feet for natural gas containing 1000 ppm H_2S. The cost for the electron beam process decreases to 0.6 cents per million for natural gas containing only 100 ppm. Approximately 4.3 trillion cubic feet of the natural gas reserves contain <100 ppm H_2S and 8.6 trillion cubic feet contain <1000 ppm H_2S. In Phase I the efficiency of H_2S removal from natural gas by electron beam irradiation will be determined. These proof-of-principle experiments will be performed on an existing all-solid-state linear induction accelerator. Based on the data from these experiments, Phase II demonstration experiments will be designed and conducted to determine the technical and economic viability of using electron beam irradiation to remove H_2S in a flowing natural gas pipeline system.

Anticipated Results/Potential Commercial Applications as described by the awardee: There exist 19 trillion cubic feet of known natural gas reserves that are not usable because of contamination by H_2S. Should this concept of electron beam irradiation be a cost effective process for removal of the H_2S, this process will be commercialized in Phase III. The electron beam technology has other applications including control of stack gas emissions, bulk sterilization of disposable medical products, and clean-up of contaminated water.

93

Sulfur Recovery from Hydrogen Sulfide-Prone Natural Gas--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Henry Eppich, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-94ER81856
Amount: $74,943

Natural gas contaminated with hydrogen sulfide (H_2S) is an environmental hazard, corrosive to natural gas distribution systems; it prohibits direct use of 19 trillion cubic feet of known natural gas reserves and 80 trillion cubic feet of undiscovered reserves. Current technologies for H_2S removal are too complex and costly. In a separate grant application, it was suggested that an electron beam process will remove H_2S from natural gas at one-third the cost of competing technologies. The electron beam process for removal of H_2S, however, decomposes it into hydrogen and elemental sulfur particulates in the size range 0.5 to 1.5 µm. Very few separation technologies efficiently remove submicron particles from gas phase flows. In this project an innovative concept, known as a Confined Vortex Scrubber, which has demonstrated 98% separation of 0.3 µm particles in air at standard conditions will be investigated. The Confined Vortex Scrubber consists of a cylindrical vortex chamber with multiple tangential process gas inlet jets. The scrubbing liquid is confined to the outer vortex chamber wall because of high radial accelerations causing small bubbles whose micro-cyclonic action is responsible for the very effective separation of submicron particles. In Phase I it will be demonstrated, via bench-top scale tests, whether the Confined Vortex Scrubber produces high submicron separation efficiencies under the much more dense conditions typical of natural gas gathering systems. These data plus scaling relations developed in Phase I will be used to design a scaled-up Confined Vortex Scrubber for Phase II feasibility tests. The Phase II project will provide the necessary scaling data and relations for carrying this technology to commercialization.

Anticipated Results/Potential Commercial Applications as described by the awardee: There exist 19 trillion cubic feet of known natural gas reserves that are not usable because of contamination by H_2S. Should the concept of electron beam irradiation/Confined Vortex Scrubber sulfur recovery be a cost effective integrated process for removal of the H_2S from natural gas, then it will be commercialized in Phase III. The electron beam and/or Confined Vortex Scrubber technology have other applications including control of stack gas emissions, bulk sterilization of disposable medical products, and clean-up of contaminated water.

COAL-BASED POWER SYSTEMS TECHNOLOGY

94

High Temperature Brazing of Silicon Carbide--Busek Company, Inc., 19 Kearney Road, Needham, MA 02194; (617) 449-3929
Dr. V. Hruby, Principal Investigator
Mrs. J. Budny, Business Official
DOE Grant No. DE-FG02-94ER81721
Amount: $74,492

The development of high performance ceramics such as silicon carbide (SiC) and silicon nitride (Si_3N_4) has progressed to the point where high temperature (~ 2000°F), highly stressed structural components operating in hostile environments can be considered. However, the technology to join such components to each other or to metals capable of high temperature operation is lacking and impedes their rapid progress into such applications as internal combustion engines, turbines, and heat exchangers. An example is the high temperature air furnace heat exchanger that has SiC as its primary tube candidate and requires a multitude of reliable gas tight joints operating at 1800°F. Therefore, this project will develop a high temperature brazed joint between SiC and a superalloy suitable for the demanding service. In Phase I, a group of test pieces will be designed and fabricated using three different filler metals and four different insert metals to accommodate induced stresses arising from difference in thermal expansion characteristics. The test pieces will undergo thorough metallographical examination and shear stress testing to determine the optimal configuration. Based on the results, a SiC tube-to-metal tube joint will be designed. In Phase II, additional test pieces will be fabricated and strength tested at 1000 and 1800°F. The tube joints designed in Phase I will be fabricated and tested at 1800°F in an oxidizing atmosphere.

Anticipated Results / Potential Commercial Applications as described by the awardee: A reliable high strength, high temperature SiC-to-metal brazed joint will find applications in many technological areas. The primary area includes energy conversion devices ranging from automotive engines to those typically found in fossil fueled plants and fusion reactors where SiC is an ideal material for the first wall. The efficiency gains realizable by the use of SiC components amply justify the planned development.

95

A Highly Efficient Two Stage Ceramic Foam Burner for Clean Combustion of Low BTU Coal Gas--Selee Corporation, 700 Shepherd Street, Hendersonville, NC 28792; (704) 697-2411
Dr. Chi-Li Lin, Principal Investigator
Mr. Kenneth R. Butcher, Business Official
DOE Grant No. DE-FG05-94ER81860
Amount: $75,000

A highly efficient two stage porous media combustor is planned which will allow clean combustion of low BTU coal gas. Experiments in Phase I will demonstrate the technical and economic feasibility of the technology. Several porous media which are suitable for this application will be investigated in detail. The combustor design and optimum operation parameters will also be developed. Based on the technology developed in Phase I, improved porous media and combustor designs as well as scaled up synthesis processes will be completed in Phase II. The pilot tests in Phase II will be designed for future commercial production and applications. Future marketing and manufacturing plans will also established in Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that porous media will enhance the efficiency of low BTU coal gas combustion. Lower pollutant emissions are also expected with this two stage porous media combustor design. The desired properties of porous media will be investigated in the Phase I project. It is also expected that the Phase I results will demonstrate the economic advantage of using the two stage porous media burners for combustion of low BTU coal gas. The pilot tests in Phase II will prove the feasibility for future commercialization of the products and processes.

96

A Long Life Zinc-Oxide-Titanium-Oxide Sorbent--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033; (303) 940-2301
Dr. Robert J. Copeland, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-94ER81881
Amount: $75,000

Coal-fired gasifier combined cycles (GCC) have both high efficiency and very low emissions. A critical need for GCCs is a method of removing the hydrogen sulfide (H_2S) produced from the sulfur in the coal from the hot gases. There has been extensive research on hot gas clean-up systems, focused on the use of a zinc oxide based sorbent (e.g., zinc titanate). Unfortunately, current sorbents can be used for only a few cycles before they either loose their activity or fall apart. A new method has been developed for producing sorbent pellets with greatly increased lifetimes. When used with a tin oxide sorbent, the pellets produced by the new methods have an estimated average lifetime of over 200 cycles under hot gas cleanup conditions. These improved fabrication methods should be directly applicable to the production of long life, low cost sorbents containing zinc oxide. The Phase I project aims to demonstrate that the process can be adapted to the leading sorbent (ZnO), optimize the sorbent composition, and measure cyclic life.

Anticipated Results/Potential Commercial Applications as described by the awardee: This new method of producing the sorbent will reduce the cost of hot gas cleanup of H_2S by increasing the life and decreasing the cost of the zinc oxide sorbent. The new method may be applicable to other absorbent applications. The low cost, long life sorbent will reduce the cost of hot gas cleanup H_2S sorbents and improve the economics of GCC.

ENHANCED OIL RECOVERY

97

A High Performance Wellbore Logging Tool Using Fiber Optic Gyro Technology--Optiphase, Inc., 7652 Haskell Avenue, Van Nuys, CA 91406-2005; (818) 782-0997
Mr. Ira J. Bush, Principal Investigator
Mr. Ira J. Bush, Business Official
DOE Grant No. DE-FG03-94ER81824
Amount: $75,000

Current state-of-the-art wellbore logging systems have been applied effectively to measure shallow vertical wells. These systems however become error prone when the wellbore inclination approaches the earth's rotation axis or approaches an orthogonal direction to earth's gravity. Additionally, when these systems are required to operate at temperatures greater than 100°C, they must be fitted with a rechargeable cooling system which impedes the measurement process and limits down hole measurement time. All of these problems are attributable to the measurement ability and limited operational temperature range of the logging instrument's spinning wheel gyros. This project involves an innovative approach to a wellbore logging instrument which eliminates the problems associated with the conventional loggers. This approach involves the use of low cost, solid state fiber optic strapdown gyros in a 3-axis measurement configuration enabling logging operations to 25,000 feet or more, operational temperature range to 200°C with indefinite operation times, accurate measurements independent of wellbore orientation, and elimination of all active down hole gyro electronics. Phase I will conduct a design analysis of the proposed fiber optic gyro concept, develop a single axis demonstration model, and conduct laboratory environmental testing to verify high performance measurement capability at temperatures up to 200°C. In Phase II a wellbore logging tool will be developed incorporating the proposed fiber gyros, and it will be field tested.

Anticipated Results/Potential Commercial Applications as described by the awardee: This new approach offers significant improvements over existing well logging systems and will become an important tool in the enhancement of oil recovery world wide.

98

A Practical High Resolution Petrographic Imaging System for Assessing Reservoir Quality--Terra Tek, Inc., 420 Wakara Way, Salt Lake City, UT 84108; (801) 584-2430
Dr. Lawrence B. Owen, Principal Investigator
Ms. Jean Jensen, Business Official
DOE Grant No. DE-FG03-94ER81886
Amount: $75,000

Drill cuttings represent a huge source of valuable data bearing on reservoir quality issues. Cuttings are produced during the drilling of every oil and gas well. However, technological innovations are lacking that would allow these materials to be utilized for assessing storage and transport properties such as effective porosity, permeability, electrical properties, capillary pressure characteristics, and geologic properties like fracture distribution, permeable pathways, and diagenetic alteration. Conventional coring and core analysis can be used to supplement well logging, but the cost of these operations and the risks that are sometimes entailed in coring deep and highly deviated wells often preclude collection of valuable reservoir quality data. The Phase I program couples an ultra-high resolution imaging technology called confocal scanning laser microscopy with state-of-the-art image analysis capabilities to form an analysis capability for direct estimation of important transport and reservoir quality parameters. The objective is to apply this new integrated technology to drill cuttings. The method can also be applied to sidewall cores, which often can not be characterized by conventional core analysis techniques owing to size constraints and the condition of specific samples which may be damaged during recovery. It has been found that intrinsic 3-D properties of porous networks, such as tortuosity, can be directly mapped by confocal microscopy permitting application of Kozeny-Carmen relationships for calculation of transport properties without over-reliance on geometric approximations. Demonstrated capillary pressure curve correlations can also be usefully applied to estimate permeability by using image analysis methods to measure the pore size distribution of samples. Biases introduced by sample surface roughness, vertical heterogeneity, and artifacts of image processing for pore separation can be eliminated by use of the optical sectioning of confocal microscopes.

Anticipated Results/Potential Commercial Applications as described by the awardee: The Phase I program will generate cuttings and sidewall core analytical protocols that will support accurate, rapid, and highly cost-effective assessment of reservoir quality factors including permeability, total porosity, effective porosity, formation factor, pore size distribution, capillary pressure response, as well as details of the permeable pathways, fracture distributions, and the impact of diagenesis on fluid storage and migration. Successful demonstration of the application of this technology will lead to a commercialization effort where the developed technology will be packaged for routine use by industry.

ROBOTS FOR NUCLEAR ENVIRONMENTS

99

Interface Designs for Telepresence and Remote Sensing Systems Using Non-Immersive Virtual Reality--Reveo, Inc., 8 Skyline Drive, Hawthorne, NY 10532; (914) 345-9555
Mr. John E. Williamson, Principal Investigator
Dr. Sadeg M. Faris, Business Official
DOE Grant No. DE-FG02-94ER81848
Amount: $74,314

Telepresence and remote sensing systems have begun to incorporate aspects of the technologies commonly called "virtual reality." This has occurred even though there have been only a few attempts to design these systems using human factors and a solid foundation in cognitive and perceptual psychology. This has resulted in systems with non-intuitive interfaces that are difficult to use. This project will advance the design of these systems using stereoscopic three dimensional (3D) displays, alternative input devices, and interface designs for non-immersive virtual reality. Traditionally, virtual reality has required the user to wear a Helmet Mounted Display (HMD) and glove. This project will treat the fact that HMDs and gloves cause more problems than they solve. Through the use of current technology, affordable, portable, high quality stereoscopic 3D images that are compatible with existing video infrastructure are possible. The system under development can integrate stereoscopic images from computer graphics packages as well as live video. The three, large stereoscopic 3D screens planned for Phase I provide a wider field of view and higher resolution at lower cost. Furthermore, this design will allow multiple users and the ability to interact unencumbered with both the projected image and other users.

Anticipated Results/Potential Commercial Applications as described by the awardee: Commercial applications include better graphical interface designs with non-immersive virtual worlds, telepresence, and complex skill acquisition. These data and resulting hardware and software designs will directly effect the design of such applications as entertainment, simulation, medical imagery, scientific visualization, air traffic control, remote sensing, and teleconferencing.

100

An Innovative Dextrous Hand Exoskeleton--Ross-Hime Designs, Inc., 1313 Fifth Street, Southeast, Minneapolis, MN 55414; (612) 379-3808
Mr. Mark Elling Rosheim, Principal Investigator
Mr. Mark Elling Rosheim, Business Official
DOE Grant No. DE-FG02-94ER81850
Amount: $75,000

DOE requires quality sensory feedback from robot to operator: fine manipulation achieved through robotic hands controlled by human-sized hand exoskeletons. These simplify and make control more intuitive when compared to keyboard or joystick control. Force feedback to these small exoskeletons requires small volume, high efficiency, semi-linear actuator mechanisms. These actuators provide human range, force, and velocity feedback to exoskeleton systems used by operators of dexterous manipulators. The design and construction of a 12-axis dextrous hand exoskeleton (DHE) is being investigated in Phase I. The DHE utilizes revolutionary force reflecting linear actuator technology and a break-through in mechanical joint technology. The application of actuator reinforced elastomer laminates replicates the flexibility of muscles and tissues in humans. The use of piezoelectric surface actuator arrays in the hand will be investigated as a method to provide a delicate sense of touch critical for detecting slippage of workpieces.

Anticipated Results/Potential Commercial Applications as described by the awardee: Prosthetics, medical speciality of physical medicine, and rehabilitation fields could utilize this technology. Control of robots, Disney-type animatronic figures, and virtual reality environments would also be enhanced.

101

A Low Cost Infrared Sensor Based System for Robotic Welding--Weld Technology, Inc., 8204 Gondola Drive, Orlando, FL 32809; (205) 887-5886
Mr. Wing Y. Chin, Principal Investigator
Mrs. Teresa S. Chin, Business Official
DOE Grant No. DE-FG05-94ER81899
Amount: $74,993

Nondestructive testing, identification, and repair of weld defects have been documented to consume as much as 25% of the total weld production cost in pipelines, ship fabrication, and power generating systems. Infrared sensor controlled welding systems have been demonstrated that would greatly reduce or eliminate expensive, after-the-fact nondestructive testing and weld repair. However, the cost of these systems has been well over $60,000, and hence commercialization of this technology has not occurred. This project will develop an infrared sensor-based system for weld process control that is nearly an order of magnitude cheaper than current systems. This cost would place this new technology well within the reach of pipeline, ship, and heat transfer piping fabricators. The large cost reduction is due to development of a new low cost infrared sensor head. In Phase I, prototype sensor heads will be constructed and tested to demonstrate the ability of the new system to identify weld perturbations which occur during commercial, large scale welding operations. The ability of the infrared sensors to identify varying depths of weld penetration and weld microstructure (mechanical properties) will be tested.

Sensor system sensitivity, response, and robustness will be examined to determine the applicability of the device to controlling the welding process in a harsh welding environment. Based upon the successful testing of the sensor system, Phase II research will lead to the development of a prototype infrared sensor-based control system for robotic welding.

Anticipated Results/Potential Commercial Applications as described by the awardee: This low cost, infrared sensor-based weld control system will greatly improve the quality and productivity of the welding process by enabling in-process control of weld penetration depth, microstructure formation, torch position, and fixturing errors. Significant decreases in costs of weld production, nondestructive examination, and weld rework are anticipated for construction and repair of nuclear and fossil energy piping, oil and gas pipelines, double hull oil tanker ships, and storage vessels.

TECHNOLOGY FOR SPACE NUCLEAR PROPULSION AND POWER

102

An Infrared Bandpass Thermophotovoltaic Filter Production Process--EDTEK, Inc., 14704 Southeast 100th Street, Renton, WA 98059; (206) 235-5163
Mr. William E. Horne, Principal Investigator
Mr. William E. Horne, Business Official
DOE Grant No. DE-FG03-94ER81742
Amount: $74,962

The conversion of infrared (IR) energy by means of photovoltaic cells, known as thermophotovoltaics (TPV), was suggested in the early 1970s and has been researched by many workers since then. The recent developments of low-bandgap photovoltaic cells and IR bandpass filters have finally made the promise of high efficiency thermophotovoltaic energy conversion a reality. This project seeks to develop a low-cost means of producing the large areas of the IR bandpass filters required for thermophotovoltaic applications. Preliminary analyses of the proposed production process indicate that the filters may be produced for as little as twenty five cents per square centimeter. Using these low cost filters, thermophotovoltaic systems could economically reach efficiencies in excess of twenty percent with IR source temperatures as low as one thousand degrees centigrade. Phase I will address the feasibility of the production process for the filters.

Anticipated Results/Potential Commercial Applications as described by the awardee: The results of the proposed effort will be a low-cost high-volume production process for IR bandpass TPV filters, raising the efficiency of TPV conversion substantially. Applications are expected in radio-isotope, nuclear, solar, and gas-fired electric powered generators. The applications range from powering deep space probes to nuclear submarines to consumer recreational vehicles.

103

High Temperature Thermally Stable Multi-Layer Quantum Well Films--Hi-Z Technology, Inc., 6373 Nancy Ridge Drive, San Diego, CA 92121-2247; (619) 535-9343
Mr. Norbert B. Elsner, Principal Investigator
Mr. Norbert B. Elsner, Business Official
DOE Grant No. DE-FG03-94ER81777
Amount: $75,000

An attempt will be made to fabricate multi-layer quantum well films (ML-QWFs) that should have an exceptionally high figure of merit (Z) from materials that exhibit very low diffusion rates. Such materials prevent the quantum well and barrier materials from interdiffusing, thereby degrading the multilayer nanostructure responsible for the improved performance. The improved performance believed to be possible with such materials is due to the confined motion of the charge carriers and the two dimensional quantum well which is in contrast to their three dimensional motion in comparable bulk materials. The layering may also decrease the thermal conductivity. The goal of this effort is to develop ML-QWFs that can operate up to 1100°C for >10 years. Parameters such as layer thickness, residual strain in the layers, and type of crystal structure will all be considered in the selection of the quantum well and barrier materials. During Phase I various boride alloys will be alternately deposited into quantum layers and their thermoelectric properties characterized.

Anticipated Results/Potential Commercial Applications as described by the awardee: ML-QWFs with a Z >1.5 will be developed that should exhibit very stable thermoelectric properties at elevated temperatures. This ultra thin film technology will allow thermoelectric devices to achieve much higher efficiencies (more than the 17% increase that is requested) and spur the low cost recovery of waste heat.

104

Nuclear Power Feasibility for Near Term Commercial Applications on the Lunar Surface--International Space Enterprises, 4909 Murphy Canyon Road, San Diego, CA 92123; (619) 637-5777
Mr. Thomas Kessler, Principal Investigator
Mr. Michael Simon, Business Official
DOE Grant No. DE-FG03-94ER81787
Amount: $75,000

Advanced commercial lunar payloads, scheduled for lunar landing later this decade, require a source of electric power that can provide continuous power at 3 to 40 kilowatts initially, with upgrades to over 100 kW. The power system must be environmentally safe and reasonably priced. Such an integrated power system does not yet exist for lunar surface payloads which experience 14 days of darkness at a temperature of -157°C. However, many building block subsystems, particularly nuclear (from which an integrated system could be constructed) do exist. The planned Phase I study will identify new subsystem requirements, confirm feasibility, and quickly integrate selected subsystems to meet near term commercial customer needs. Results will include conceptual hardware designs, operations concepts, and commercial financing assessment of solutions to the following key technical problems: heat rejection during lunar day and night, site survey and selection to avoid radiation susceptible soils, site preparation for reactor emplacement, physical deployment of a reactor by robotic means, manufacture of radiation shielding in-place, thermal coupling of radiation shielding with the reactor and surrounding soil, radiation shielding compatible with in-place changes to heat exchanger connections to allow upgrade from direct electric to Stirling cycle, and power transmission methods to fixed and mobile commercial instruments.

Anticipated Results/Potential Commercial Applications as described by the awardee: Advanced lunar surface power represents an enabling technology for scientific and commercial applications that can contribute many millions of dollars to the U.S. economy. Sales of nearly $900 million are projected from the first seven lunar missions (1997 to 2000). If this initial level of activity is augmented by a significant number of foreign payloads, total sales through 2000 could exceed $2 billion, not including sales relating to development of payloads.

105

Hydrogen Permeation Barriers for Bimodal Reactors--Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601; (717) 569-6551
Mr. John R. Hartenstine, Principal Investigator
Mr. Richard W. Longsderff, Business Official
DOE Grant No. DE-FG05-94ER81888
Amount: $74,987

Bimodal space nuclear power systems which combine both thermal propulsion and electric power generation capabilities in a single integrated power and propulsion platform have recently emerged as strong candidates for future military and commercial space applications. For propulsion, the reactor heats hydrogen which is exhausted through a nozzle to provide propulsive thrust. Thermal energy from the reactor is also converted to electricity by in-core or out-of-core energy converters. One issue of concern in a bimodal system is the potential for hydrogen permeation into energy conversion components. At bimodal reactor temperatures, hydrogen will permeate through the refractory metal structures degrading the operational capabilities of in-core thermionic converters, or heat pipes used to transmit heat from the reactor to the out-of-core energy converters. This project will develop and demonstrate a hydrogen permeation barrier using a trilayer assembly with a thermally conductive porous powder metal layer between two containment walls. Hydrogen that permeates through the first containment wall is vented from the porous powder metal to the vacuum of space prior to permeation into critical components. Hydrogen permeation resistant coating will also be evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of this program should result in the development of a hydrogen permeation barrier to protect critical components on space nuclear thermal propulsion and power systems. This technology could be used for Stirling heat engine electric power generators which currently use helium gas. Hydrogen gas can increase the system efficiency. The trilayer assembly could be used as a hydrogen permeation barrier making hydrogen Stirling engines feasible.

TECHNOLOGY TO SUPPORT AND IMPROVE NUCLEAR FUEL CYCLE PROCESSES

106

A Long Life Perovskite Oxygen Electrode for Calcium Oxide Processing in Nuclear Fuel Cycles--Eltron Research, Inc., 2830 Wilderness Place #E, Boulder, CO 80301; (303) 440-8008
Dr. Anthony F. Sammells, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG02-94ER81751
Amount: $74,997

This project is directed towards developing novel electrocatalysis for oxygen evolution in electrolytic cells used for promoting calcium oxide splitting. The molten salt to be electrolyzed will be contained within a dense, oxygen anion conducting, solid electrolyte tube. The overall technical approach will be systematically pursued in four distinct stages during Phase I as follows: 1) fabricate electrolytic cells, 2) conduct an electrochemical study on both half and full cells, using steady-state, cyclic voltammetry and transient voltage-step current-voltage measurement techniques to gain insight into the performance of selected anodes for oxygen evolution, 3) perform anode electrocatalyst optimization, and 4) fabricate and electrochemically test electrolytic cells for the simultaneous generation of separated calcium and oxygen using optimal experimental conditions.

Anticipated Results/Potential Commercial Applications as described by the awardee: Development of this technology will be expected to provide electrolytic cells incorporating novel oxygen evolution anodes compatible with simultaneous generation of separated calcium and oxygen from calcium oxide for application in nuclear fuel processing.

107

Oxygen-Evolving Anodes for the Electrolysis of Calcium Oxide--EMEC Consultants, 4221 Roundtop Road, Export, PA 15632; (412) 325-3260
Dr. Rudolf Keller, Principal Investigator
Dr. Rudolf Keller, Business Official
DOE Grant No. DE-FG05-94ER81752
Amount: $75,000

Electrochemical reduction of calcium oxide is an effective step in the processing of spent nuclear fuels by the Salt Transport Process. It is desirable to conduct this electrolysis with oxygen-evolving anodes, thereby avoiding carbon contamination, but the feasibility of this approach has not yet been established. Three candidate anode materials will be examined for CaO electrolysis in laboratory experiments similar to those previously conducted in other systems. Anode stability shall be established and electrolysis conditions identified at which no chlorine gas forms. It is planned to expand the effort to include the electrolysis of lithium oxide.

Anticipated Results/Potential Commercial Applications as described by the awardee: The project should identify promising anode candidates to improve a process step in the recycling of nuclear fuel. The technology has potential to provide more cost-effective and energy-efficient production of calcium and other metals.

MEASUREMENT OF MECHANICAL PROPERTIES IN CIVILIAN NUCLEAR REACTOR FACILITIES

108

Fracture Toughness Testing with Minimal Material--Packer Engineering, Inc., Plant Component Analysis Division, 200 Fleet Street, Pittsburgh, PA 15220; (412) 921-6441
Dr. James A. Begley, Principal Investigator
Dr. James A. Begley, Business Official
DOE Grant No. DE-FG05-94ER81825
Amount: $74,811

The feasibility of using minimum sized specimens from broken halves of Charpy specimens to fully characterize the transition range fracture toughness of reactor pressure vessel steels will be evaluated in Phase I. There are well known effects of specimen size on measured fracture toughness values. The use of specimens of minimum size requires accounting for these size effects. This will be done by using a combined constraint/statistical approach to interpreting cleavage fracture toughness measurements. Since substantial plasticity will occur during toughness testing, the J (elastic-plastic) integral parameter will be used to characterize the plastic stress/strain environment near the crack tip. Differences in constraint (stress triaxiality) as a function of specimen type and size will be treated by computing crack tip plastic stresses and strains and expressing these results in terms of a parameter termed Q. Long crack tip lengths sample more material than short lengths. Sampling size effects will be incorporated by using Weibull weak link statistics. The optimum fracture toughness specimen configuration which can be machined from one half of a broken Charpy specimen will be evaluated by a combined experimental and analytical study. Techniques for automatic machining of this configuration will also be evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase I results should provide the basis for a definitive combined analytical and experimental verification of this technique to conduct cleavage range fracture toughness tests with minimal material. It should also provide a basis to develop a fully automated specimen preparation procedure involving minimum waste products.

PERSONAL MONITORING FOR PARTICULATES

109

A Programmable Particulate Sampling System--Anatole J. Sipin Company, Inc., 505 Eighth Avenue, New York, NY 10018; (212) 695-5706
Mr. A. J. Sipin, Principal Investigator
Mr. A. J. Sipin, Business Official
DOE Grant No. DE-FG02-94ER81705
Amount: $72,400

Personal sampler pumps are worn by industrial workers to determine the concentration of particulates to which the worker has been exposed during a work shift. Usually a particulate collection device, such as a filter, is worn in the breathing zone of the worker and connected to a belt-mounted pump through a flexible tube. This is cumbersome, and occlusion of the tube can cause an erroneous measurement. Although current pumps maintain a constant air flow rate during sampling for accurate determination of sampled volume, they must be initially set with a flowmeter, and frequent calibrations are required. In Phase I a system will be investigated in which the sampler pump includes a miniature pneumatic pumping unit that has a weight of 4.4 oz and a volume of 8.8 cubic inches. This unit is sufficiently small to be close coupled to the filter in the breathing zone, eliminating problems with flexible filter tubes. The control system used provides an accurate selected flow rate by internal calibration that is stable over a long period. Setting with an external flowmeter or calibrator is unnecessary. A self test feature to check the calibration is also provided. To prevent accidental interference with operation, or tampering with the pump, sampling valves are externally programmed.

Anticipated Results/Potential Commercial Applications as described by the awardee: This sampling system should lead to a significant advance in particulate monitoring technique and apparatus. There is a substantial market for an improved dust sampler in industrial applications.

EDUCATIONAL TECHNOLOGY: ELECTRONIC GAME DEVICES FOR MATHEMATICS, SCIENCE, AND ENGINEERING

110

Development of a Computer Game Prototype to Teach Physical Geography--Gautier-Downes and Associates, 2656 Montrose Place, Santa Barbara, CA 93105; (805) 682-8824
Dr. Catherine Gautier, Principal Investigator
Ms. Jeannette Gautier-Downes, Business Official
DOE Grant No. DE-FG03-94ER81770
Amount: $74,992

There is a presently recognized need for improved geographical science education that can be met by the development of technologically innovative computer games. Therefore, this project will create a prototype adventure computer game (title) based on realistic role playing. It will run on a high performance platform, the 3DO Interactive Multiplayer system developed by Panasonic. The purpose of this project is to teach high school students facts and concepts in physical geography through particular phenomena of importance to the earth system. The planned prototype will be built on El Nino during Phase I of this project. This initial choice of El Nino is guided by previous work done on the development of computer-based educational material. The overall structure would allow the development of other titles that will be added during Phase II which will include monsoons and the exploration of the earth from space. The overall objective is for high school students to learn what El Nino is, how and why it forms, what its impact is, and how it is investigated by playing the scientist's role involved in its study. This will provide students with an introduction to the main disciplines of physical geography: meteorology, oceanography, climatology, and some biology through El Nino causes and effects on weather, sea surface temperature, level of phytoplankton, and fish population. This project will also introduce the students to some of the new tools used by scientists studying physical geography and El Nino such as remote sensing and numerical/mathematical modeling. Finally, students will learn how major scientific investigations are performed and under what constraints. This project will have different levels of complexity from introductory physical geography (fact-based) to in-depth meteorology and oceanography (concept-based).

Anticipated Results/Potential Commercial Applications as described by the awardee: During Phase I a prototype computer game will be developed and tested. The outcome of Phase II will be the final version of this game that will be marketed to high schools.

111

An Intelligent Tutoring Game to Teach Scientific Reasoning--Research Development Corporation, 2875 Towerview Road, Suite A4, Herndon, VA 22071; (703) 904-1808
Dr. John Leddo, Principal Investigator
Dr. John Leddo, Business Official
DOE Grant No. DE-FG05-94ER81847
Amount: $75,000

Today's workforce requires ever increasing competence in math, science, and engineering skills. Unfortunately, recent surveys suggest that the U.S. rank at the bottom of industrialized nations in scientific competence of its students. This jeopardizes our long term outlook for leadership in a high tech world. One educational challenge to remedy this is to teach science more the way scientists view it, namely as an evolving process of inquiry, rather than as a body of facts and "truth" as most people commonly view it. Further, science and math should be taught in an enjoyable context to increase interest. One solution to meet both of these criteria lies in a marriage of intelligent tutoring system (ITS) and electronic game technologies. This project would create an intelligent tutoring game (ITG) to teach the techniques of scientific inquiry that scientists have, while delivering an individualized program of instruction that is both enjoyable and tailored to the specific learning needs of each player. Phase I will be devoted to testing the feasibility of this approach by: (1) defining the topics and skills to be taught, (2) developing an instructional approach, (3) developing an ITG framework, (4) developing a proof-of-concept ITG, (5) evaluating the ITG, and (6) preparing and delivering the final report. Phase II will be devoted to developing and testing a full-scale ITG. Phase III will be devoted to commercializing the Phase II ITG.

Anticipated Results/Potential Commercial Applications as described by the awardee: Potential commercial applications include electronic games to teach scientific reasoning skills that mirror those of scientists. These can be marketed for such systems as Nintendo and Genesis. Such games would have the advantages of teaching much needed skills while being enjoyable and therefore encouraging learning.

112

KIDVID - Mathematics Games by Kids for Kids--
The Lightspan Partnership, Inc., 2382 Faraday Avenue, Suite 300, Carlsbad, CA 92008; (619) 929-5900
Dr. Inabeth Miller, Principal Investigator
Mr. John Kernan, Business Official
DOE Grant No. DE-FG03-94ER81735
Amount: $75,000

Nearly 90% of American households with eight-year-old children own video game devices. However, the use of video games as a potential learning opportunity has not been exploited by schools, parents, or the research community. The Phase I project aims to develop three video game prototypes with progressive levels of challenges to help children explore rational number concepts and apply them to the real world. The prototypes will be based upon game ideas generated by children and their teachers. The effort is intended to discover (1) whether the utilization of children to develop educational games results in games that children find appealing; (2) whether video games can be an effective means of increasing children's interest in and understanding of mathematics; and (3) the flexibility and practicality of using a computerized authoring system to prototype and modify products in a fluid design environment. The learning embodied in the video games will be compatible with the curriculum standards set forth by the National Council of Teachers of Mathematics.

Anticipated Results/Potential Commercial Applications as described by the awardee: Children who play with the video game prototypes will have a better understanding of and attitude toward rational number concepts. The commercial outcome of our research will be to create a model for a line of curriculum based educational video games. The products will be marketed to schools as well as homes.

GREEN CAR: SCIENTIFIC APPROACHES TO AUTOMOTIVE INNOVATIONS

113

A Low Emission Alkali Metal Thermal to Electric Converter Automotive Power System--
Advanced Modular Power Systems, Inc., 4667 Freedom Drive, Ann Arbor, MI 48108; (313) 677-4260
Dr. Thomas K. Hunt, Principal Investigator
Dr. Thomas K. Hunt, Business Official
DOE Grant No. DE-FG02-94ER81696
Amount: $74,558

The Alkali Metal Thermal to Electric Converter (AMTEC) is a static energy conversion device that operates at thermal to electric conversion efficiencies that are independent of size, have reached 19% and are expected to reach 25% to 30% in early 1995. These systems operate silently, with no moving parts and can utilize any source capable of delivering heat at 700oC to 900oC. Because they are as efficient as small internal combustion engines over a wide range of output (within 5% of peak efficiency from 15% to 85% of full power), but use external combustion, they are expected to have the lowest emissions possible for a given electrical output. Their output is DC, and, with appropriate series connection of modules, AMTEC can deliver voltages to match those provided by the battery systems of electric vehicles either for charging or for direct operation of electric motor drives. While AMTEC systems have been under development for years, recent developments made in programs directed toward spacecraft power systems have led to much simpler cell designs, far higher reliability, greatly improved modeling methods, and a clear path to modules appropriate for the assembly of multi-kilowatt systems. This project will demonstrate the feasibility of this approach through design, analysis, and the fabrication and testing of subscale modules. In Phase I a system design will be developed and used to guide a series of experiments whose results will allow a clear test of the feasibility of the AMTEC approach. Phases II and III will demonstrate full scale module performance and show that they can be assembled into units appropriate for use in a hybrid-electric vehicle. The experimental work in Phase I will develop the first multi-tube vapor-vapor AMTEC module and use its performance to refine the state-of-the-art analytical models for AMTEC. The models will then be used to determine the feasibility of a full scale system and direct the statement of work for Phase II. The Phase II program will have input from the automotive industry.

Anticipated Results/Potential Commercial Applications as described by the awardee: In Phase III, auxiliary power units for hybrid-electric vehicles will be assembled and tested in vehicles. They will be able to improve vehicle range and reduce emissions to well below expected standards. As stand-alone modules, the same AMTEC devices that can be assembled into large systems for vehicles can be utilized as residential generators in continuous gas furnaces, for remote power in recreational vehicles, for rural power generation from biomass fuels, and for cathodic protection of pipelines.

114

Advanced Catalysts for Ultra-Low Emission Control in Natural Gas Fueled Vehicles--
Goremotive Industries, Inc., 20944 Sherman Way, Suite 206, Canoga Park, CA 91303; (818) 884-0015
Mr. Y. E. Chang, Principal Investigator
Mr. Arthur D. Sweet, Business Official
DOE Grant No. DE-FG03-94ER81772
Amount: $75,000

Two catalyst formulations are planned which should significantly advance performance and durability of emission control converters for use in light duty vehicles converted for use with compressed natural gas (CNG) or dual (gasoline and CNG) fuels. Research in Phase I will formulate and experimentally examine key performance parameters for (1) catalysts designed to resist sintering and maintain nitrogen oxide reduction activity and three-way catalytic activity at elevated temperatures, and (2) catalysts designed to convert carbon monoxide, non-methane organic compounds, and methane at low temperatures. The feasibility of new flexible configurations of emission control converters capable of three way catalyst (TWC) coupling and specifically designed to exceed Ultra Low Emmission Vehicle standards with CNG fuel will be examined. Research tasks will include:

- Development of a sintering-resistant NO_x reduction catalyst designed to operate in (hotter) locations closer to the exhaust manifold than current underfloor converters.
- Evaluation of coatings designed to inhibit oxidation of new commercial ferritic steels used in electrically heated converters (EHC).
- Development of TWC catalyst with high oxygen storage capability and high activity for CO and hydrocarbon oxidation at low temperature.

Anticipated Results/Potential Commercial Applications as described by the awardee: The advanced catalytic system would allow conversion of gasoline vehicles to CNG to produce several significant economic benefits previously not clearly attributable to CNG vehicles. Because the catalyst designs are expected to result in ultra-low emissions for NO_x and non-methane organic compounds, a departure for the traditional reductions solely in CO and particulates, these vehicles could become a potential source of cost-effective emissions reductions aimed at attaining both NO_x and ozone air quality standards. CNG conversion is effectively a vehicle recycling program; therefore 1) it is cost-effective to reduce emissions from vehicles whose market value exceeds the price offered by scrapping programs; 2) consumers need not purchase a new car to achieve the reductions (as is the case with most alternative vehicle programs; and 3) the emissions reductions are relatively permanent for the life of the vehicle and exceed those reductions achieved by simple replacement with new gasoline engines.

115

A Clean and Efficient Thermophotovoltaic Generator for Electric Vehicles--JX Crystals, Inc., 1105 12th Avenue, Northwest, Suite A, Issaquah, WA 98027; (206) 392-5237
Dr. Lewis M. Fraas, Principal Investigator
Mrs. Jany Xiang Fraas, Business Official
DOE Grant No. DE-FG03-94ER81795
Amount: $74,932

A quiet, lightweight, clean electric power source will be built, in which natural gas burns continuously in a ceramic tube, the tube glows red hot, and photovoltaic cells receive the infrared radiation from this emitter and convert it to electric power. In effect, "solar" cells are used with a manmade "sun" created by burning natural gas. Because the natural gas is burned at a continuous high temperature in the photovoltaic unit, it is expected to burn more completely and cleanly than it does in the periodically exploding internal combustion engine. Initial benchtop experiments have already shown that this generator is fifty times cleaner with respect to hydrocarbon and carbon monoxide emissions. Such a generator has only recently become feasible as a result of newly fabricated gallium antimonide cells. These new cells are much more sensitive in the infrared spectrum than traditional solar cells. In Phase I, a small benchtop thermophotovoltaic generator will be built, and sufficient data collected to demonstrate that such a generator can operate cleanly and efficiently at economical power densities. The long term goal of this project is to build a generator with sufficient power to charge onboard vehicle batteries, resulting in an electric vehicle without the present constraint of limited driving range. Further, the design of this generator will emphasize cost-effectiveness in volume production, so that this project could lead to commercially viable products in all present and future markets for electric generators.

Anticipated Results/Potential Commercial Applications as described by the awardee: Thermophotovoltaics generation has the potential to replace all existing small electric generator applications and create several major new markets. As cogenerators of electricity and heat, thermophotovoltaic generators are capable of entering the remote residential market in the next three years. Larger markets include electric vehicles, and electric utility- distributed generation via customer cogeneration in residential and commercial buildings and industrial facilities. Lower cost electricity generation is the benefit driving the creation of these markets, but other important benefits include increased fuel efficiency, lower emissions, and reduced foreign oil dependence.

116

Molecular Composite Plastics for Lightweight Green Cars--Maxdem, Inc., 140 East Arrow Highway, San Dimas, CA 91773; (909) 394-0644
Dr. Mark Trimmer, Principal Investigator
Dr. Matthew Marrocco, Business Official
DOE Grant No. DE-FG03-94ER81806
Amount: $74,749

It is planned to replace both metals and glass fiber composites in automotive construction. Potential savings in weight of 25% to 40% over current materials and the ability to recycle these new thermoplastics offer major steps toward a fuel efficient Green Car. For example, the Lightweight Materials Program Plan projects that if current vehicles were lightened by only 25% the total U.S. gasoline consumption would drop 13%. The planned new materials are based on new rigid-rod resins. These plastics are stiffer and stronger than any isotropic thermoplastic, with up to four times the stiffness and two times the strength of high performance thermoplastics like polyimides and polyetherketones. In Phase I, the planned new blends are targeted to replace sheet molding compounds (SMC). While no method of recycle exists for currently used SMC body panels, the new blends would contain no fibers and are potentially recyclable. Ultimate properties would allow displacement of metals, including primary structural applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: The first commercial application for the new materials is expected to be molecular composite sheet for automobile body panels. A weight savings of about 40% would result in addition to full recyclability, and improved surface finish because of the elimination of glass fibers. Ultimately these molecular composites are expected to displace metals in primary structural applications.

117

A Membrane Reactor for the Production of Hydrogen Fuel from Hydrocarbon Liquids--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025; (415) 328-2228
Dr. Ingo Pinnau, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-94ER81808
Amount: $75,000

Research and development efforts are under way to produce the "green car"—an energy-efficient, pollution-free, economical vehicle that is also appealing to consumers. A good approach to meeting the goals of the "green car" is to use a fuel that is energy-efficient, pollution-free, economical, and safe. This project will investigate an innovative membrane-based process that would make hydrogen feasible as an automobile fuel. Ultrathin metal composite membranes will be used in an on-board membrane reactor to produce extremely pure hydrogen fuel by dehydrogenation of hydrocarbon liquid. The spent liquid is stored in the automobile and recycled at the filling station, enabling the "green car" to use the existing fuel supply network. The use of a hydrocarbon liquid as the hydrogen source eliminates the problem of fuel safety. In Phase I, catalytically active metal membranes on high-temperature polymer supports will be prepared and characterized. The membranes will be installed in a membrane reactor to determine the hydrogen conversion efficiency and production rate. The size, cost, and weight of a membrane reactor to power a 2,000-lb automobile will be estimated. In Phase II, the membranes will be scaled up for a pilot-scale membrane reactor to demonstrate the continuous production of hydrogen as an automotive fuel.

Anticipated Results / Potential Commercial Applications as described by the awardee: If successfully developed, the resulting lightweight, efficient membrane reactor could be used to generate hydrogen fuel from hydrocarbon liquids in the "green car" of the future.

118

Surface Hardening of Polymeric Composites by High Energy Ion Irradiation--UES, Inc., 4401 Dayton-Xenia Road, Dayton, OH 45432-1894; (513) 426-6900
Dr. Rabi S. Bhattacharya, Principal Investigator
Mr. Robert W. Vukusich, Business Official
DOE Grant No. DE-FG02-94ER81894
Amount: $74,769

The recent major advances in surface hardening of polymers by ion irradiation opened up the opportunity for replacing many current parts in the automotive industry. There are many gear applications where the use of polymers is desirable from the standpoint of noise, cost, and/or weight reduction. However, polymers tend not to do well in wear and friction applications because of their low hardness compared to steels or other metals suitable for gear applications. High energy (MeV) ion implantation has been shown to improve the hardness of many polymers quite significantly. Surfaces of some polymers became harder than that of steel after ion irradiation. In Phase I, ions at energies in the range 2-6 MeV will be implanted into six different glass reinforced polymers considered for small gear applications in automotive industry. The implanted materials will be characterized for surface hardness, static and dynamic friction coefficients, and wear coefficients. The results will be analyzed with respect to the needs for automotive gear applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: A new method based on high energy (MeV) ion irradiation will be developed for the improvement of surface hardness, friction, and wear properties of glass reinforced polymeric composites. The potential applications are in the automotive, aerospace, and chemical industries.

119

An Energy Efficient Electric Vehicle--Visual Computing Systems Corporation, 9540 Highway 150, Box 250, Greenville, IN 47124; (812) 923-7474
Mr. Roy Kessinger, Jr., Principal Investigator
Mr. Robert J. Westerkamp, Business Official
DOE Grant No. DE-FG02-94ER81898
Amount: $74,817

This project is pursuing the design and production of a line of integrated mechanical, electronic, and software modules to provide a logical framework within which motion control systems of great efficiency and versatility may be designed and constructed. These products are called general-purpose motion modules (GPMs). GPMs are, in effect, mechatronic electric motor systems, integrating the motor, transmission, sensing, and control functions for a single axis of motion into a lightweight modular package. This functional integration will achieve significant reductions in size and weight, while increasing output torque and electromechanical conversion efficiency. Due to the high power-to-weight ratio of these devices, as well as their high operating efficiency, automotive applications are particularly appropriate for GPM technology. Phase I will expand the current GPM baseline designs to allow their use in numerous automotive systems. A high-level design will be produced, at the mechanical, electrical, and control levels, of a vehicle employing a regenerative powertrain based on general-purpose motion modules (GPMs). Current GPM designs will be modified to provide the high torque and high efficiency required by practical electric vehicles. Predictions of overall vehicle efficiency will be produced. Throughout the project, computer-based simulation will be employed to facilitate design and to allow system performance to be predicted.

Anticipated Results/Potential Commercial Applications as described by the awardee: The proposed effort will produce motor and controller concepts for high-efficiency passenger cars, commercial trucks, and military vehicles. The concepts for efficient high-torque rotary actuators will be valuable in numerous electric drive applications, including industrial motors, material handling, and robotics.

DESIGN AND APPLICATIONS OF NOVEL MATERIALS

120

Economical Photochromic Films for Solar Thermal Control--EIC Laboratories, Inc., 111 Downey Street, Norwood, MA 02062; (617) 769-9450
Dr. R. David Rauh, Principal Investigator
Dr. A. C. Makrides, Business Official
DOE Grant No. DE-FG02-94ER81743
Amount: $75,000

The goal of this work is to develop a robust thin film coating, less than 1 μm thick, that can be applied to surfaces, rendering them photochromic in sunlight with respect to both the visible and near infrared components of the solar spectrum. Applied to windows these single layer "chromogenic" coatings are projected by modelling studies to result in large energy savings by solar management, particularly in buildings dominated by their cooling load. The planned thin film approach would differ from current photochromic technologies which are generally silver-based. Current technologies are not easily adapted to architectural glass and require bulk glass or environmentally sensitive polymer host materials. The coatings will be derived from inorganic transition metal oxides, and are thus expected to be economical in materials and preparation, robust, and not subject to environmental degradation. The objective of Phase I is to demonstrate a new highly active photochromic thin film employing a novel means of sensitization of the metal oxide photocoloration process. The thin films may be prepared by vapor deposition (to be investigated in Phase I) or by thermal decomposition of appropriate precursors, compatible with float glass plant operations. Successful completion of the project will yield a 6 in. square sample of the new material and preliminary performance and life testing results. This will form a basis of a more extensive Phase II project in which the composition and processing are optimized, and in which the long term environmental stability of the materials is characterized and improved.

Anticipated Results/Potential Commercial Applications as described by the awardee: In the commercial sector, a truly economical photochromic coating would be useful in building windows, automotive windows, sunroofs for thermal and glare control, and for eyewear. Aircraft cockpits would also benefit from photochromic materials both in thermal control and in enhanced visibility of displays in bright sunlight.

121

A Novel Method for Manufacture of High Temperature Superconducting Coils for High Temperature Operation--IGC Advanced Superconductors, 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Leszek R. Motowidlo, Principal Investigator
Mr. B. A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81780
Amount: $75,000

The primary objective of this project is the development of high temperature superconducting (HTS) coil technology suitable to produce at least one Tesla (T) at pumped liquid nitrogen temperatures. The Phase I project will continue to develop a new approach for increasing the performance of HTS coils for high temperature operation. The technical approach being followed in this work will allow achievement of critical current densities (J_c) equivalent to the best results obtainable by short sample pressing. The achievement of J_c values on the order of 30,000 to 60,000 A/cm^2 in the final coil configuration would then allow, for the first time, serious consideration of devices to be operated at cryogenic temperatures such as pumped liquid nitrogen (64 K) with magnetic field generation of at least one Tesla.

Anticipated Results/Potential Commercial Applications as described by the awardee: Significant commercial market opportunities for superconductivity in the near future (10 to 20 years) will be realized in two basic fields. The first is medical (less than 2.5 T) and non-medical (2.5 T to 12 T) applications of nuclear magnetic resonance (NMR) techniques, and the second will be energy technology, including the eventual commercial growth of superconducting magnetic energy storage on both a large (> 10 MJ) and small (1 to 10 MJ) scale. For example, low cost NMR or magnetic resonance imaging magnets requiring only low fields (0.8 to 1 T) and cooled by cryogenic gases to 60 K could be made available.

122

Thermophotovoltaic Generator Efficiency Improvement--Quantum Group, Inc., 11211 Sorrento Valley Road, San Diego, CA 92121; (619) 457-3048
Dr. Glen A. Holmquist, Principal Investigator
Dr. Mark Goldstein, Business Official
DOE Grant No. DE-FG03-94ER81838
Amount: $74,500

The objective of the Phase I effort is to perform a feasibility/modeling study for a high temperature (1700 to 2200°C), combustion powered, high efficiency thermophotovoltaic electrical generator. The combination of existing materials and technologies will be tested and brought together to achieve the high efficiency goal. Superemitters that concentrate radiant flux in quantum transitions emission peaks are available for study and measurement. New photovoltaics that match the superemitter peaks with efficient photon conversion are becoming economically feasible.

Anticipated Results/Potential Commercial Applications as described by the awardee: The result of this effort will be the ability to produce new higher efficiency and environmentally friendly electrical power generators to replace existing systems, in areas such as residential electrical peak load leveling, quiet generator systems, and low nitrogen oxides burners and generators.

123

A Novel High Strength Ceria-Zirconia Toughened Alumina Ceramic with Superior High Temperature Corrosion and Erosion Resistance--Selee Corporation, 700 Shepherd Street, Hendersonville, NC 28792; (704) 697-2411
Dr. Giulio A. Rossi, Principal Investigator
Mr. Kenneth R. Butcher, Business Official
DOE Grant No. DE-FG05-94ER81859
Amount: $75,000

This project will develop a novel ceramic material, made of a ceria-zirconia (CeO_2-ZrO_2) toughened alumina (Al_2O_3), which is expected to exhibit superior strength and corrosion (alkali, sulphate) and erosion resistance in high temperature environments, such as coal-derived hot gases. This material will be fabricated for convenience in the shape of a reticulated foam in order to provide enough surface area to alkali and sulphate exposure and to compare its performance with other foams with different compositions. The open cell structure will be made by impregnating a polyurethane foam with an aqueous ceramic slurry, followed by drying and firing to burn the organic material and densify the foam struts at high temperatures. Samples of the material will be exposed to alkali- and sulphur-containing species at high temperatures, and the change in physical, chemical, and mechanical properties will be measured, vis-à-vis selected reference materials.

Anticipated Results/Potential Commercial Applications as described by the awardee: A strong, corrosion and erosion resistant CeO_2-ZrO_2 toughened Al_2O_3 material will be developed. Its primary commercial application is in ceramic particulate filters for coal-derived hot gases, where it could replace inadequate existing materials such as aluminosilicates and non-oxide ceramics.

124

Design and Applications of Close-Spaced Thermionic Converters with Novel Isothermal Electrodes--Space Power, Inc., 621 River Oaks Parkway, San Jose, CA 95134; (408) 434-9500
Mr. Gary O. Fitzpatrick, Principal Investigator
Mr. Joseph A. Dodson, Business Official
DOE Grant No. DE-FG03-94ER81864
Amount: $74,342

It will be demonstrated in Phase I by analysis and experiment that electrodes for thermionic converters having heat pipes incorporated in the electrode structure accommodate high interelectrode heat flux without distortion. These results will enable close-spaced converters with electrode gaps of 5 µm or smaller. Such a converter can be 13% efficient with an emitter temperature of only 1300 K. This is a new approach to enhanced energy conversion efficiency which can significantly increase overall efficiency of power generation at competitive cost. The analysis of the electrodes will consider heat transfer, mechanical deformation, and thermionic performance. Trade-off of heat flux and physical dimensions will lead to an optimum design. Experiments will use laser interferometry to characterize and confirm the capabilities of the isothermal electrode. An application study will quantify the commercial benefits that can reasonably be expected from this improved performance, which can be commercialized in this decade. Follow-on work would include fabrication of an operating module of close-spaced thermionic converters with the isothermal electrodes.

Anticipated Results/Potential Commercial Applications as described by the awardee: Thermionic conversion at high efficiency and relatively low temperatures can be incorporated as topping cycles to steam and/or gas turbine electric generation, as solar thermal generators, and for cogeneration. Significantly enhanced overall efficiencies mean benefits economically and in resource utilization.

125

Rare Earth Endohedral Fullerenes as New Nonlinear Optical Materials--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033; (303) 940-2301
Mr. John Michael Alford, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-94ER81880
Amount: $75,000

Computers using light beams instead of wires are the fastest known type of computer. Many of the main components of optical computers such as the optical switches that are its fundamental building blocks are fabricated from third order nonlinear optical (NLO) materials. Unfortunately, the best currently available third order materials have NLO effects that are two to four orders of magnitude smaller than are needed for commercial devices driven by moderate power diode lasers. Endohedral fullerenes (closed cage carbon molecules with a rare earth atom or atoms trapped inside) are believed to possess large optical nonlinearitites. Significantly, these predicted nonlinear effects are optimally located for use with infrared (IR) laser diodes. Additionally, electronic interactions between the fullerene and metal atom may provide a natural way to obtain optical control of the materials properties and allow for optical switching of the nonlinearity. In spite of the fact that endohedral fullerenes were first produced almost three years ago, insufficient material exists to determine if they actually have the NLO properties predicted by the theorists. This is primarily a result of the difficulty in purifying the materials. Therefore, in Phase I a new type of large scale preconcentration step will be used along with high performance liquid chromatography to purify sufficient quantities of endohedral fullerenes for NLO characterization. The optical properties of the materials will be measured using four wave mixing spectroscopy and other types of nonlinear spectroscopy.

Anticipated Results/Potential Commercial Applications as described by the awardee: Endohedral fullerenes are predicted to have large NLO properties that would make them ideal materials for use in devices such as optical computers. Additionally, the development of a practical method for producing endohedral fullerenes will allow sales of these materials to researchers and, ultimately, to commercial users.

126

Development of Metal Hydride Materials for High Coefficient of Performance Heat Pumps--
Thermal Electric Devices, Inc., 1009 Bradbury Drive, Southeast, Albuquerque, NM 87106; (505) 272-7505
Dr. K. Thomas Feldman, Jr., Principal Investigator
Dr. Charles Stein, Business Official
DOE Grant No. DE-FG05-94ER81890
Amount: $74,999

This project will develop improved metal hydride materials for a new hydride heat pump that is environmentally clean and potentially twice as efficient as the best current systems. New thermodynamic processes have been developed for hydride heat pumps that are significantly more efficient and utilize no chlorofluorocarbons (CFCs), which must be phased out of use by 1995. The best current refrigerators operating with less damaging hydrochlorofluorcarbon (HCFC) refrigerants have a coefficient of performance or COP = 1.5, while the proposed new hydride heat pump has a theoretical COP = 3.3. Current research has demonstrated that hydride heat pumps are feasible and very promising, but improved hydride materials are needed to achieve their full potential. Improved hydride heat exchangers are needed that have more rapid heat transfer and hydrogen flow. Hydrides have low thermal conductivity so that rapid heat transfer into and out of the hydride bed is difficult. Also, hydride particles tend to become smaller and compacted during use and this blocks the free flow of hydrogen into and out of the hydride bed. In Phase I the approach to the improved hydride materials involves coating the metal hydride particles with a thin layer of copper and then compressing the coated particles into porous heat exchangers which can provide more rapid and effective heat transfer and hydrogen flow. When developed, this technology will allow nearly a 50% reduction in the electric power required by refrigerators/freezers, air conditioners, and heat pumps used in both domestic and commercial applications including vehicles. The new system will be smaller, weigh less, and cost about the same as conventional refrigeration equipment. The system does not require CFCs or HCFCs, so it is inherently clean and has no adverse environmental impact.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase I will develop, build, and test improved hydride materials and heat exchangers optimized for a new high performance hydride heat pump. Based on the positive results of preliminary research, it is anticipated that the research will develop improved hydride materials and highly effective hydride heat exchangers that will allow nearly the full potential of the more efficient hydride heat pump to be realized.

MATERIALS SCIENCES INSTRUMENTATION

127

X-Ray Absorption Spectroscopy for Trace Analysis of Chemical Phase and Composition--Advanced Fuel Research, Inc., 87 Church Street, P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. David B. Fenner, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG05-94ER81861
Amount: $74,674

X-ray absorption spectroscopy (XAS) based at synchrotron facilities is an established research tool in a variety of fields including biochemistry, catalysis, and materials science. For trace analysis, XAS offers important phase information as well as elemental composition. Commercialization will depend on increased performance of the x-ray detection system. This Phase I project will leverage university expertise and DOE laboratory facilities by transferring improved techniques to the private sector small business. An improved detector system is planned, based on an array of silicon avalanche photodiodes having the following advantages: (1) operation at or near room temperature, (2) internal signal gain and lower noise, (3) good efficiency up to ~15 keV, and (4) good energy discrimination. This detector will improve on conventional germanium (Ge) and silicon (lithium) Si(Li) detectors primarily by elimination of the bulky cooling apparatus, thereby reducing the cost and increasing the overall flexibility. Application to analysis of the chemical phase of trace metal compounds in soils will form an early demonstration of the power of this technique. The information gained from this project will also contribute to evaluation of the potential for application of the technology to related areas of x-ray research.

Anticipated Results/Potential Commercial Applications as described by the awardee: Benefits include an increase in the cost effectiveness of the XAS technique, thereby enhancing the commercial potential for analytical services based on this technique for use in the growing fields of biochemistry, environmental control and remediation, and others. There is also a considerable market for an inexpensive, high-performance x-ray detector in the many government, academic, and industrial research institutions which already utilize XAS in their research activities.

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An Apparatus for Structural Analysis of High Temperature Materials Using Synchrotron Radiation--Containerless Research, Inc., 910 University Place, Evanston, IL 60201-3149; (708) 467-2678
Dr. Shankar Krishnan, Principal Investigator
Dr. Paul C. Nordine, Business Official
DOE Grant No. DE-FG02-94ER81732
Amount: $74,978

X-ray and neutron scattering are powerful techniques for structural measurements on solids and liquids. Although structural analyses of high temperature materials are important, they have been limited by two sources of error. First, the materials of interest become contaminated by reaction with their containers. Second, the containers produce unwanted scattering and absorption of the probe beams. These errors combine to produce intractable problems in the analysis of data. These problems will be eliminated in this project by applying containerless techniques for x-ray and neutron scattering measurements on high temperature liquids and solids, both metals and ceramics. The methods for achieving containerless conditions will be electromagnetic levitation for metallic materials and conical nozzle levitation for both metals and ceramics. The electromagnetic levitation approach was demonstrated in preliminary neutron scattering experiments. The conical nozzle method was demonstrated in the laboratory on molten aluminum oxide and other ceramics. The main goal of the project is to develop the x-ray analysis of high temperature materials using the conical nozzle technique with synchrotron radiation. The conical nozzle levitation method will be investigated for metallic and ceramic liquids of interest during Phase I. The research will include synchrotron scattering experiments on levitated materials of known structure, using the National Synchrotron Light Source. Phase II would provide a portable apparatus for application at synchrotron radiation and neutron beam facilities for structural analyses of high temperature materials.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of Phases I and II will provide a breakthrough in making accurate structural measurements of high-temperature materials routinely feasible. It will eliminate the extreme difficulty of container interactions at high temperatures. It will enable structural studies on highly corrosive materials of industrial importance such as battery and plating materials, slags, and semiconductors. The planned work will provide a new analytical tool to apply synchrotron radiation in measurements of scientific and industrial interest.

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A Novel Detector for Neutron Diffraction Studies--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Dr. Gerald Entine, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-94ER81841
Amount: $75,000

The objective of this project is to develop a new type of large area position sensitive neutron detector for use in diffraction studies. The detector would use a liquid crystal sensing mechanism to provide a large area high resolution (comparable to photographic methods) detector which would be inexpensive to produce. To demonstrate the feasibility of this concept in Phase I, several technical areas need to be examined. First, research will be carried out on modifying the solution chemistry of the liquid crystal systems to determine if neutron sensitive boron compounds can be incorporated. Second, the electro-optic characteristics of candidate liquid crystal systems will be examined, and finally, the modified liquid crystal systems will be tested for neutron sensitivity. Phase II of this effort will continue the research and examine the fabrication of prototype position sensitive arrays. The detector would provide substantially increased performance at lower cost than existing detectors used in neutron diffraction studies

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned detector would offer performance advantages over existing instruments and would be inexpensive to manufacture. The resulting detectors would find widespread use in material science research and may also be useful in industrial neutron tomography applications.

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An Analytical Research Materials Characterization Facility Based on Synchrotron Radiation--X-Ray Analytics, Ltd., Box 678, Upton, NY 11973; (708) 887-9941
Dr. Kevin L. D'Amico, Principal Investigator
Dr. Kevin L. D'Amico, Business Official
DOE Grant No. DE-FG02-94ER81901
Amount: $74,710

This work represents an effort to establish a materials characterization facility at a synchrotron radiation source which can be utilized on a fee-for-service, pay-as-you go basis by industrial research, development, and production organizations. The ultimate outcome of the program is the existence of a beamline facility dedicated to both analytical service and contract research. The Phase I effort will be to identify the materials and the analytical problem that can be addressed with a synchrotron radiation technique. This technique will be the basis for the beamline capabilities. Experiments will be performed on the materials to demonstrate that routine results can be obtained. The potential for scale-up will be addressed, with the goal of showing that the measurements can be done routinely at an existing synchrotron radiation source. A conceptual design for a prototype beamline which is optimized for routine analytical measurements will be developed.

Anticipated Results/Potential Commercial Applications as described by the awardee: This effort will result in the growth of the market for the synchrotron radiation-based characterization of materials by industrial research organizations nationwide and in the further use of these techniques by industrial laboratories not currently utilizing them. This will provide for the more effective transfer of technology from the federally-funded laboratories, where the synchrotron radiation facilities exist, to the private research laboratories not currently using them.

IMPROVED ONSTREAM METHODS OF NONDESTRUCTIVE EVALUATION

131

Application of the Meandering Winding Magnetometer to an In-Situ Determination of Age Related Degradation--Jentek Sensors, Inc., 1616 Soldiers Field Road, Boston, MA 02135; (617) 254-5552
Dr. Neil J. Goldfine, Principal Investigator
Dr. Neil J. Goldfine, Business Official
DOE Grant No. DE-FG02-94ER81792
Amount: $75,000

Many of the structures and components important to safe operation of power plants are susceptible to age related degradation. Steam lines suffer creep damage, Inconel steam generator tubes suffer stress corrosion cracking, reactor vessels become embrittled, and cyclically loaded components may experience fatigue damage. Nondestructive characterization of these age related degradation mechanisms would provide the information required for informed decisions regarding plant maintenance and life extension. No techniques exist that provide adequate information. A novel sensor, the Meandering Winding Magnetometer (MWM), offers considerable promise as a new means of nondestructive, on-line, in situ material characterization. It has already been shown to be capable of precise measurements of conductivity in nonferromagnetic materials. Conductivity is known to be sensitive to age related degradation, and permeability may be as well. The MWM also offers the possibility of measuring depth related variations in electromagnetic properties. This feature may be especially useful as several forms of age related degradation are known to vary with depth. Phase I will investigate extending the capability of the MWM to provide conductivity and permeability data for ferromagnetic materials. It will also investigate the relationship of material properties and sensor response to fatigue damage, one form of age related degradation. Phase II will extend MWM inspection capabilities to address creep damage. It will also include integrating the MWM sensor into a field portable prototype instrument.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phases II and III should produce a complete, field portable inspection system capable of nondestructively characterizing several age related damage mechanisms in a variety of materials. For power plant operators, this could be a powerful tool for managing age related degradation and making critical decisions related to plant life extension. The concept has great commercial potential, since it could save millions of dollars in reduced downtime caused by catastrophic failures.

ADVANCED GEOPHYSICAL IMAGING IN GEOSCIENCES RESEARCH

132

A Superconducting Magnetometer/Gradiometer for Advanced Geophysical Imaging--Conductus, Inc., 10623 Roselle Street, San Diego, CA 92121; (619) 550-2700
Dr. Douglas N. Paulson, Principal Investigator
Dr. Duane B. Crum, Business Official
DOE Grant No. DE-FG03-94ER81730
Amount: $75,000

There has recently been increased interest in the use of active electromagnetic measurements to provide improved imaging of subsurface structures, particularly for enhanced oil recovery and environmental issues such as ground water contamination, underground petroleum leaks, and remediation of hazardous waste sites. Borehole-to-borehole and surface-to-borehole measurements are of particular interest since they provide better information about the subsurface structure than a surface-to-surface measurement. Although induction coils are available for use in boreholes, it is difficult to get good sensitivity to horizontal fields. These coils are expensive and/or physically large which tends to limit their widespread use. Recent advances in the performance of superconducting quantum interference device (SQUID) sensors made from the new high-temperature superconductors have been significant. It is now possible to use these sensors to build compact, low-noise, multi-element magnetometer arrays. Phase I will develop a simple prototype magnetometer system incorporating one or more high-temperature SQUID sensors. This magnetometer will be interfaced to a ruggedized data acquisition system and its performance and noise level measured in a variety of operating conditions.

Anticipated Results/Potential Commercial Applications as described by the awardee: This new sensor, along with its associated analysis tools, should provide significant benefits in a number of surface and borehole applications including environmental remediation, enhanced oil recovery, unexploded ordnance detection, ground water contamination, and petroleum leakage.

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High Resolution Mapping of Mechanical and Flow Properties of Suburface Structure from New Methods for Acoustic Logging Data Processing--New England Research, Inc., 76 Olcott Drive, White River Junction, VT 05001; (802) 296-2401
Mr. Xiaoming Tang, Principal Investigator
Mrs. Beth K. Potter, Business Official
DOE Grant No. DE-FG02-94ER81818
Amount: $74,962

In the exploration and production of oil and gas reservoirs and in groundwater studies, there is a need for high resolution mapping of fluid flow channels in the subsurface formation. The increased resolution provides accurate locations of the flow channels and helps enhance the recovery of hydrocarbon resources. For environmental applications, the accurate mapping of the flow channels will help track contaminants and pollutants associated with groundwater flow. To achieve this goal, effective sensing technologies and high resolution processing techniques need to be developed. The objective of this project is to develop high resolution techniques for single well acoustic logging data processing to obtain in-situ estimates of permeability and mechanical properties of subsurface formation and to locate and characterize bedrock fractures. As a result, subsurface flow systems and their transmissivity (or permeability) will be accurately mapped to provide useful information for enhanced oil and gas recovery and for the characterization and remediation of soil and groundwater contamination problems. Phase I will address two major tasks. The first is to develop the high resolution processing technique to include the conventional full waveform acoustic logs. The second is to develop analysis methods for high resolution permeability estimation from tube waves and test the methods using available data. The completion of these tasks will determine the applicability of the proposed techniques for high resolution mapping of subsurface structure.

Anticipated Results/Potential Commercial Applications as described by the awardee: High resolution techniques to resolve subsurface flow units from acoustic logging data processing should result from this project, as well as a high resolution processing software package that will be commercially available to oil and gas, environmental, and hydrological industries.

CHEMICAL SCIENCES RESEARCH

134

An Advanced Electrochemical Sensor for the Simultaneous Analytical Measurement of Three Chemical Species--Andcare, Inc., 2810 Meridian Parkway, Suite 152, Durham, NC 27713; (919) 544-8220
Dr. Marek Wojciechowski, Principal Investigator
Ms. Carolyn J. Henkens, Business Official
DOE Grant No. DE-FG05-94ER81706
Amount: $75,000

The requirements of complex sample monitoring present a growing need for a new generation of highly specific enzyme electrodes with multi-analyte, multi-signal capability. This project's objective is to establish the feasibility of novel electrochemical sensors based on the combination of immobilized enzymes and colloidal gold technologies. The specific goal to be pursued in Phase I is to demonstrate the feasibility of an in-vitro lipid profile diagnostic device for the simultaneous detection of total cholesterol, high density lipoproteins, and triglycerides using a disposable biosensor. This lipid profile testing is an important part of current recommendations for reducing cardiac risk and for monitoring therapy for millions of individuals with cardiovascular disease. Deposition of colloidal gold with immobilized enzymes onto separate channels of a multi-channel surface to provide spatially resolved, multi-signal enzyme electrodes can ultimately lead to a new generation of multi-analyte sensors.

Anticipated Results/Potential Commercial Applications as described by the awardee: A new marketable micro-scale, multi-analyte sensor based on novel enzyme immobilization methods will result in a device of improved rapid analytical characterization of multi-component systems.

135

High-Performance Membranes for Gas, Vapor, and Liquid Separations--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. Dwayne T. Friesen, Principal Investigator
Dr. Rod Ray, Business Official
DOE Grant No. DE-FG03-94ER81903
Amount: $75,000

Separation processes to recover and purify products account for more than 40% of the energy demand in the Chemical Process Industry (CPI), but membrane processes have gained only a small share of this major market. Conventional membranes have had limitations that have precluded their widespread acceptance in the CPI and other industrial settings. Specifically, membranes either could not withstand exposure to harsh solvents and high temperatures involved in industrial separations or lacked the high permeability and high selectivity to be commercially practical. The goal in this project is to develop a new class of polymers that addresses these limitations. The plan is to apply these high-selectivity, high-permeability polymers to unique solvent- and temperature- resistant hollow-fiber supports to form thin-film-composite membranes suitable for use in the CPI. These membranes will be suitable for applications involving the separation of aromatics from aliphatics (e.g., benzene from gasoline) and olefins from paraffins (e.g., propylene from propane). Phase I, should demonstrate the feasibility of using membranes based on this new class of polymers for aromatic/aliphatic and/or olefin/paraffin separations. A series of membranes will be incorporated into small-scale (200-cm^2) solvent- and temperature-resistant hollow-fiber modules, and tested extensively. Phase II will optimize the polymers for separation targets, make larger (1m^2) modules, and perform pilot-scale tests. The tests will generate the data necessary to set specific technical and marketing targets for commercialization of the technology in Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: The polymers to be developed in this project--combined with the solvent- and temperature-resistant hollow-fiber supports developed in previous--work should make possible the use of membrane-based separation systems for a range of applications in CPI. In addition to the separation of aromatics from aliphatics and olefins from paraffins (two of the largest classes of separation in the CPI), other types of separations may be possible, such as the separations of ethyl benzene from styrene or the separation of butylene isomers.

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Photoaffinity Immobilization of Fusion Proteins on Biosensor Surfaces--BSI Corporation, 9924 West Seventy Fourth Street, Eden Prairie, MN 55344; (612) 829-2715
Dr. Patrick E. Guire, Principal Investigator
Mr. Stephen A. Richards, Business Official
DOE Grant No. DE-FG02-94ER81720
Amount: $74,280

This project is designed to resolve a critical and enduring obstacle to the development of dependable biosensor systems for the timely detection of toxic and infectious agents. A passivated sensor surface will be developed that will associate uniquely with the specific binding protein in its crude source solution and, upon activation by light, covalently bond this protein functionally oriented in a stabilizing, biomolecule-compatible environment. A trifunctional amino acid will be derivatized on one site with a photoactivatable reagent capable upon illumination of forming covalent bonds with essentially any organic target group (including all proteins) under mild reaction conditions. This reagent will then be thermochemically bonded to a ligand for the specific binding protein and to the sensor surface previously passivated with a photoreactive hydrogel, to provide an essentially aqueous environment containing chosen ligand and photoreactive groups adjacent on the sensor surface. This passivated photoaffinity sensor surface will be exposed to aqueous protein mixtures and tested for its efficiency and specificity in photochemical immobilization of the desired binding protein, as well as the storage and use stability of the immobilized sensor protein. In the Phase I effort, a passivating coating for glass surfaces and a photoreactive trifunctional reagent will be prepared, which will be reacted with the passivated surface and with a ligand to provide a photactivatible affinity surface. This photoaffinity glass is expected to reduce non-specific protein binding by at least 75% and to immobilize the fusion protein with greater than 50% recovery of DNA-binding activity. Phase II will optimize the reagents and coating process for two or more fusion proteins and demonstrate the feasibility of this chemistry for patterned immobilization on biosensor surfaces.

Anticipated Results/Potential Commercial Applications as described by the awardee: Civilian uses of this biomolecule-compatible photoaffinity sensor surface technology are expected to include the monitoring for hazardous and metabolic (health-relevant) substances in water, air, animal feeds, foods, and physiological fluids. The Department of Defense could use the technology in the development of one or more advanced sensor devices for the timely detection of hazardous chemical and biological agents in water, air, and materials.

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Organic-Inorganic Composite Membranes for Gas Separation and Vapor Permeation--CeraMem Corporation, 12 Clematis Avenue, Waltham, MA 02154; (617) 899-0467
Dr. Richard J. Higgins, Principal Investigator
Dr. Robert L. Goldsmith, Business Official
DOE Grant No. DE-FG02-94ER81723
Amount: $75,000

The development of specifically engineered polymers and appropriate module designs in the past decade has made possible the commercialization of gas separation membrane technology for several industrial applications. Since currently available membranes and modules are based upon use of organic polymeric materials, they generally are limited to applications involving temperatures of less than about 100°C. However, there are several potential commercial applications for gas separation membrane technology that involve temperatures in the range of about 100°C to 300°C. For these, commercially viable membranes or modules are currently unavailable. In Phase I, cost-effective gas-permeable membrane modules based on low-cost ceramic supports will be developed. Such modules will be designed for use at temperatures in the range of 100° to 300°C. An innovative method will be used to apply thin, defect-free membranes, based on thermally resistant polymers, to the ceramic supports. The resulting membrane modules will subsequently be tested at temperatures ranging from 100°C to 300°C for gas separation and vapor permeation properties using two-component gas mixtures.

Anticipated Results/Potential Commercial Applications as described by the awardee: The gas separation/vapor permeation devices to be developed in this project, if successfully scaled up to production-scale ceramic modules in Phase II, would provide a potentially economic membrane-based alternative to competing technologies for many elevated temperature gas separation processes in industrial chemical manufacturing and the petrochemical and refining industries.

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Electrode Materials for Rechargeable Lithium Batteries--Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706; (602) 574-1980
Dr. R. O. Loutfy, Principal Investigator
Dr. J. C. Withers, Business Official
DOE Grant No. DE-FG02-94ER81805
Amount: $75,000

Fullerenes are a newly discovered form of carbon (graphite and diamond are the other two forms) with distinctive properties and an unusual molecular structure. Preliminary investigations indicated that fullerene electrode materials exhibit unique electrochemical properties. In this Phase I effort, fullerene nanotube structures will be investigated as novel electrode materials for lithium ion storage and supply for rechargeable lithium batteries. Fullerene electrodes will be fabricated by various techniques and fully characterized. The nature of the electrochemical charging and discharging of fullerene nanotubes as a function of operating conditions will be established. The lithium intercalated fullerene nanotubes as a function of operating conditions will be established. The lithium intercalated fullerene (C_nLi_x) electrodes will also be characterized including their capacity, stability, charge and discharge characteristics, and efficiency to establish their viability for a high efficiency secondary battery as a power source for portable electronic equipment.

Anticipated Results/Potential Commercial Applications as described by the awardee: Fullerenes are a newly discovered material with potentially unique properties. Preliminary results indicate that fullerene electrodes could be used to store energy with applications in secondary batteries. The feasibility of this concept could lead to novel electrochemical systems for energy storage and generation.

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Highly Selective Membranes for the Separation of Organic Vapors Using Super-Glassy Polymers--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025; (415) 328-2228
Dr. Ingo Pinnau, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-94ER81811
Amount: $75,000

The recovery of organic compounds from air and of higher hydrocarbon vapors from methane are related separations of considerable industrial importance. Membranes able to preferentially permeate the minor organic component are being developed for both of these applications. For an efficient process, a high organic vapor/ permanent gas selectivity is required. Conventional glassy polymers, which are selective for the permanent gas over the organic vapor, are suitable for this application. Rubbery polymers, which are organic vapor selective, are in commercial use, but have inadequate selectivity for many applications. Recent work showed that multi-free-volume, super-glassy polymers such as poly(1-trimethylsilyl-1-propyne) [PTMSP] can exhibit a butane/methane selectivity of 30 with the mixed gases. This selectivity is the highest ever observed for this important mixture and is completely unexpected for a glassy polymer. The reason for this extraordinary result is related to the high free volume and the large intermolecular chain spacing of the super-glassy polymer. In this Phase I project, a detailed study will be conducted of the vapor separation properties of PTMSP, related polyacetylenes, and blends thereof with a number of important organic vapor/gas mixtures. In contrast to results of previous studies of high free volume glassy polymers with permanent gases, these polymers are expected to show stable permeation properties in the presence of organic vapors.

Anticipated Results/Potential Commercial Applications as described by the awardee: Membranes made from high-free-volume glassy polymers could have a significant impact on many important industrial vapor separations. Possible applications include recovery of high hydrocarbons from natural gas, removal of hydrocarbons from hydrogen in the petrochemical industry, and recovery of hydrocarbon vapors from gasoline storage tanks. The superior selectivity and permeability of superglassy polymers relative to state-of-the-art rubbery membranes will make membrane systems competitive with conventional separation methods such as cryogenic separation in these or other applications.

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Novel High Performance Glassy Polymer Composite Membranes for Gas Separation--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025; (415) 328-2228
Dr. Richard W. Baker, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-94ER81810
Amount: $75,000

In the last decade, many high-performance glassy polymers, such as polyimides, that combine high gas permeability and high selectivity for one gas over another have been developed. Although these new membrane materials have vastly better intrinsic gas separation properties than the materials in current use, essentially none has been used in commercial membranes. The problem is the lack of adequate, reproducible, large-scale membrane fabrication technology that is applicable to these polymers. In this Phase I project, a new method will be developed for preparing high-performance membranes from glassy polymers. Unlike existing commercial membranes made from glassy materials, the membranes will be multilayer composites in which the glassy selective layer is coated onto a high-flux support. The support itself will have two layers, a microporous substrate and a thin, highly permeable sealing layer. General principles will be derived for making optimized multilayer composite membranes with selective layer thicknesses of less than 0.1 µm from any given glassy polymer, and membranes with potential applications for specific gas separation applications will be identified.

Anticipated Results/Potential Commercial Applications as described by the awardee: A general method of producing ultrathin, defect-free composite membranes with highly selective glassy polymers on a commercial scale would have a significant impact on many gas separation applications such as oxygen/nitrogen separation or removal of carbon dioxide or hydrogen sulfide from natural gas. The use of advanced composite membranes would dramatically improve the overall process economics, and make membrane systems competitive with conventional separation methods in these or other applications.

HIGH PERFORMANCE COMPUTING RESEARCH

141

Parallelization of Pseudospectral Algorithms for Electronic Structure Calculations--Schrödinger, Inc., 80 South Lake Avenue, Suite 735, Pasadena, CA 91101; (818) 568-9392
Dr. Murco N. Ringnalda, Principal Investigator
Dr. Murco N. Ringnalda, Business Official
DOE Grant No. DE-FG03-94ER81852
Amount: $74,880

Electronic structure programs are becoming an increasingly powerful tool for solving chemical and biological problems without costly experiments, but in order to use current and future computer hardware to maximal advantage, they must be parallelized efficiently. The pseudospectral (PS) approach utilized in the previously developed PS-GVB software package is grid-based, permitting a well-balanced distribution of tasks for each region of the grid, which will lead to effective parallelization. The resulting increase in speed will make PS-GVB even more useful for ab initio predictions of electronic structure of large molecules. Phase I will parallelize the most computationally intensive portions of PS-GVB: the assembly of the least-squares operator, the Fock matrix, the GVB Hamiltonians, and the Lanczos-type eigensolver used for updating the wavefunction during the self-consistent field process. The resulting program modifications will be tested using Parallel Virtual Machine (PVM) software on workstation clusters. The ultimate Phase III goal of the parallelization effort is a multifunctional software package that distributes all tasks effectively when run on a wide variety of massively parallel processors and clusters.

Anticipated Results/Potential Commercial Applications as described by the awardee: The complete, parallelized PS-GVB program should be of use to a large number of researchers in the chemical, biological, and materials sciences in both government and industry. We expect that for many applications, the unique mixture of functionality and efficiency in parallel PS-GVB will make it the only effective solution.

ATMOSPHERIC MEASUREMENT AND SAMPLING TECHNOLOGIES

142

A Tunable Room Temperature Infrared Laser for Measuring Atmospheric Pollutants--Aerodyne Research, Inc., 45 Manning Road, Billerica, MA 01821; (508) 663-9500
Dr. Roger S. Putnam, Principal Investigator
Dr. Charles E. Kolb, Business Official
DOE Grant No. DE-FG02-94ER81698
Amount: $74,911

Solid state laser sources currently available for measuring greenhouse gases, combustion products, and other species across the 3 to 30 micron region are lead salt diode lasers which operate at liquid nitrogen temperatures. Practical problems include the need for cryogenic cooling, erratic tuning behavior, and limited availability of single mode devices in this region. The opportunity exists to apply inexpensive, room temperature diode lasers which are now readily available with enough power to directly drive a nonlinear difference-frequency infrared generator. The facts that the new diode lasers produce enough power, are available with 10 MHz linewidths without an external cavity, are tunable, and are remarkably efficient make this application an immediate opportunity. The Phase I objectives involve the basic demonstration of generating tunable infrared in the 10 micron region using diode lasers and a gallium selenide crystal with a unique optical design which compensates for beam walk-off and permits the wide tunability of an angle-tuned system with nearly the same conversion efficiency possible in a 90° phase-matched system. The calculated 10 micron power of 0.25 microwatts will result in the desired absorption sensitivity of 10^{-5}/cm in one second, using a standard 1 mm mercury cadmium telluride detector with a detectivity of 4×10^{10} and a 0.6 meter long multipass cell with a 100 meter path length.

Anticipated Results/Potential Commercial Applications as described by the awardee: An inexpensive tunable source of narrowband infrared permits the construction of air monitoring equipment for a wide variety of pollutants. The market for this instrument already exists in this period of increased environmental concern, attendant legal issues, and new regulations.

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A Robust Gas Monitor for Remote Environments--DR Technologies, Inc., 12555 High Bluff Drive, Suite 280, San Diego, CA 92130-2056; (619) 794-9607
Dr. Edward A. Johnson, Principal Investigator
Mr. Lyle E. Dunbar, Business Official
DOE Grant No. DE-FG03-94ER81738
Amount: $74,888

Infrared (IR) absorption spectroscopy is a standard laboratory technique for analyzing gas samples, but good IR absorption instruments are expensive, complicated, and delicate, sharply limiting their usefulness for remote and unattended atmospheric monitoring. This project will develop a rugged, self-calibrating IR absorption sensor that has many of the desired characteristics. With no moving parts, this device can measure concentrations of many gasses by measuring spectra approaching the quality of laboratory IR absorption instruments, at a cost comparable to simple catalytic sensors. In its ordinary operating mode, this multispectral sensor operates at high pulse rates and provides accurate chemical information on a few millisecond time-scale for immediate use in an active feedback control system. A unique feature of this device is that it is self-referencing; this should provide excellent stability and allow for long counting times with phase-locked detection and a consequent improvement in sensitivity. The Phase I project will evaluate the sensitivity of a multispectral sensor using phase-locked detection and self-referencing for stability. In addition, the Phase I project will explore photoacoustic detection and extended sampling with unclad optical fibers in order to extend the detection limits. These tests will establish the basic design and performance characteristics of a prototype instrument to be built and demonstrated in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: An analytical chemical sensor that is highly sensitive, selective, robust, and of low cost will have wide commercial and government applications for industrial process control and environmental monitoring. This would be an important scientific tool for ecological and atmospheric research.

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A Subvisible Volcanic Dust Cloud Imager--
Physical Sciences, Inc., 20 New England Business Center, Andover, MA 01810-1077; (508) 689-0003
Dr. David M. Sonnenfroh, Principal Investigator
Mr. George E. Caledonia, Business Official
DOE Grant No. DE-FG02-94ER81830
Amount: $75,000

This project will develop a design for a prototype airborne, remote, subvisible volcanic dust cloud sensor. This innovative, compact instrument is based on a passive, tuneable, infrared, imaging spectroradiometer. The sensor exploits differences in the particle absorption cross sections between silicon dioxide (SiO_2) and water in the 8 to 12 μm region to sensitively detect and discriminate between hazardous dust clouds and nonhazardous natural water clouds by their thermal self-emission. This instrument will have the sensitivity to provide this discrimination at distances of over 15 miles. The Phase I effort includes airborne instrument design and laboratory validation experiments.

Anticipated Results/Potential Commercial Applications as described by the awardee: The project will result in a conceptual design for an airborne imaging spectroradiometer capable of detecting and discriminating between hazardous and nonhazardous subvisible aerosol clouds. Demonstration of the detection of SiO_2 clouds will be achieved using an existing preprototype imager. The instrument would have commercial applications in remote monitoring of manufacturing plants or waste remediation sites for hazardous chemical and aerosol emissions and in manufacturing process monitoring as a high speed temperature sensor.

BACTERIAL IDENTIFICATION AND SAMPLING

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Development and Application of Gene Probes to Determine Degradation Potential and to Improve In-Situ Bioremediation Efforts--
Envirogen, Inc., 4100 Quakerbridge Road, Lawrenceville, NJ 08648; (609) 936-9300
Dr. Robert J. Steffan, Principal Investigator
Mr. William J. Guarini, Business Official
DOE Grant No. DE-FG05-94ER81759
Amount: $75,000

The goals of this project are to develop a method to rapidly generate gene probes to identify and monitor indigenous degradative microorganisms at polluted sites and degradative organisms added to augment natural populations, and to use the probes as a predictive tool for determining degradative potential for selecting appropriate treatment conditions. The probes will also be used to assess the progress of treatment so timely adjustments can be made to maintain optimum treatment performance. The probes will be generated by using a novel arbitrarily primed polymerase chain reaction (AP-PCR) protocol that generates a "fingerprint" of degradative strains, and allows the selection of unique DNA fragments which will function as sub-strain specific probes. The AP-PCR probes allow the detection of individual strains without relying on homology to probes based on already-cloned degradative genes, thereby allowing detection of strains with novel degradative genes or strains not detected by "standard probes". Gene probing will be performed in conjunction with the use of novel DNA extraction and fractionation protocols which separate the community DNA based on its % G+C. These protocols allow the analysis of the total microbial community including non-culturable cells, and improve the sensitivity of detecting specific organisms. They also provide a mechanism for monitoring gross changes in the microbial community in response to environmental changes, thereby allowing adjustment of treatment conditions to optimize performance.

Anticipated Results/Potential Commercial Applications as described by the awardee: The results of this work should provide a mechanism to monitor the progress of, and optimize, in situ bioremediation efforts. These methods would allow for reduction in costs of in situ bioremediation by improving performance (increased rates and improved efficiency) of treatment systems, thereby improving the commercial advantage of biological solutions to waste treatment. They may ultimately lead to the development of commercial kits for estimating degradative potential of sites to determine best treatment strategies, and to monitor the progress and efficiency of treatment.

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Bacterial Identification from Environmental Samples by Phospholipid Fatty Acid Analysis--
MIDI, Inc., 115 Barksdale Professional Drive,
Newark, DE 19711; (302) 737-4297
Dr. Myron Sasser, Principal Investigator
Dr. Myron Sasser, Business Official
DOE Grant No. DE-FG05-94ER81812
Amount: $70,795

Research on in-situ remediation of subsurface pollution and hazardous wastes includes studies on the identification of bacteria in such sites. The origins, distributions, and relationships to environmental conditions are facilitated by learning the identity of the bacteria present in the sites. Highly desirable would be the identification of organisms directly from the soil without the necessity of getting the organisms into pure culture. Phase I will explore the use of supercritical fluid extraction of bacterial lipids directly from soil samples, followed by derivitization and gas chromatographic analysis. Use of the electron capture detector with fluoro esters will provide enhanced sensitivity for detection of relatively small numbers of organisms. The resulting complex mixture of fatty acids will be studied using biomarker fatty acids (compounds unique to a limited class of organisms) to identify major species components of the mixed population. Another algorithm will then use the biomarker information to set up a matrix of possible species combinations and compare the results of the matrix to the complex profile. This should make possible reasonable estimates of the percentage composition of each of the major bacterial species in a complex consortium.

Anticipated Results/Potential Commercial Applications as described by the awardee: The major anticipated result is a technique for identification of bacteria directly from environmental samples without overnight culturing. In addition to applications in the bioremediation area, the research should have clinical applications for detection of bacteria directly from tissues. It might also find utility in pharmaceutical applications in identification of mixed cultures in microbiology quality control.

HEALTH EFFECTS

147

An Automated DNA Probing, Sizing, and Sequencing System--Gamera Bioscience Corporation, 30 Memorial Drive, Cambridge, MA 02142; (617) 441-1080
Dr. Alec Mian, Principal Investigator
Dr. Alec Mian, Business Official
DOE Grant No. DE-FG02-94ER81769
Amount: $74,948

Over the last decade, research in human molecular genetics, fueled by a variety of technological innovations, has undergone enormous advances. Gel electrophoresis, Southern hybridizations, DNA sequencing, and polymerase chain reaction are examples of techniques that have greatly facilitated the discovery and characterization of disease-causing DNA polymorphisms. Unfortunately, the transfer of these technologies from research laboratories into diagnostic clinical laboratories has been difficult, mainly for two reasons. First, many of the abovementioned techniques, especially gel electrophoresis and Southern hybridizations, require skilled personnel and are difficult if not impossible to automate. Second, the technological agendas for research laboratories can be very different from diagnostic laboratories; the former is concerned with discovery and technological flexibility, and the latter with dedicated, automated, high-throughput systems. This project is concerned with a novel gel-free detection system that seeks to unite some of the more cumbersome diagnostic techniques into a single, simple, automated instrument. The technology will allow (1) sizing of small (<200 - 300 bases) DNA fragments, (2) accurate and sensitive probing and detection of amplified or genomic DNA sequences, and (3) sequencing of short stretches of DNA (20 - 50 bases) such as sequence tag sites (STSs). Although such a technology may only have limited application in research laboratories (because of short DNA sizing and sequencing capacities), it is especially attractive to diagnostic laboratories: the sizing and sequencing capacities are sufficient for the detection of polymorphisms, and it is rapid and easily automated for high throughput. Phase I will characterize the parameters and feasibility of the DNA probing, sizing, and sequencing aspects of the technology. In Phase II, automation and scale-up to 96-well format will be proposed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result of this project is a system that will analyze short polymorphic stretches of DNA by direct sizing, probing, and/or DNA sequencing. The anticipated ease of use, rapid run times, and high throughput of such an instrument should find ready commercial application in clinical diagnostic laboratories involved in the screening of human polymorphisms and genetic diseases. In addition, the instrument's capacity to merge presently disparate genetic diagnostic technologies is expected to accelerate consolidation, standardization, and acceptance of human genetic diagnostic tests.

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Signal Amplification for Specific Nucleic Acid Detection--Third Wave Technologies, Inc., 2800 South Fish Hatchery Road, Madison, WI 53711-5399; (608) 273-8933
Ms. Mary Ann D. Brow, Principal Investigator
Dr. Lance Fors, Business Official
DOE Grant No. DE-FG02-94ER81891
Amount: $75,000

This project will attempt to commercialize a novel, high-speed, and automatable DNA and RNA diagnostic technology for the specific detection of nucleic acid sequence changes associated with genetic diseases. This technology is based on the discovery that the 5' nuclease of several thermostable DNA polymerases can be engineered to direct cleavage of DNA or RNA at one and only one location, allowing the development of a very fast, sensitive, specific, and isothermal cleavage-based detection technology. Phase I should show that the signal released from the recognition of the target sequence can be propagated through an amplifying cleavage cascade. This will entail optimization of conditions for cleavage, further characterization of the enzyme activity, and testing of the molecules involved in the amplification cascade. Phase II would complete the development of this broad-based nucleic acid detection technology that can play a significant role in making cost-effective, large-scale early detection, diagnosis, and monitoring of a wide variety of diseases a reality.

Anticipated Results/Potential Commercial Applications as described by the awardee: The fast, simple, specific, sensitive, reliable and user-friendly technology for the detection of DNA and RNA sequences and sequence changes developed in this project will significantly increase the speed and decrease the cost of detecting, diagnosing, and monitoring a wide variety of diseases and disorders.

HUMAN GENOME

149

Estimating, Encoding, and Utilizing Uncertainties in Sequence Data--Computational Biosciences, Inc., P.O. Box 2090, Ann Arbor, MI 48106; (313) 426-9050
Mr. John Hartman, Principal Investigator
Mr. John Hartman, Business Official
DOE Grant No. DE-FG02-94ER81729
Amount: $74,999

Among the stated goals of the Human Genome project is a dramatic improvement in DNA sequencing technologies and corresponding reduction in cost per finished base sequenced. Relatively little attention, however, has been given to the problem of assuring the quality of the rising tide of mass-produced data as genomic sequencing becomes ever more automated and production-oriented. At a very minimum, it will be incumbent on the producers of sequence data to provide information regarding its reliability, preferably for each sequenced base. This will require that such information be estimated as automatically and as inexpensively as is the sequence data itself. This Phase I project will address this issue by achieving the following broad objectives: (1) approaches to the estimation of base-specific uncertainty information from the outputs of automated sequencing machines will be studies and evaluated, (2) methods for compactly encoding, storing, viewing, and manipulating this information will be implemented and evaluated, (3) a fragment assembly algorithm will be designed that utilizes this information for input fragments and generates consistent estimates for finished assemblies, and (4) a variety of sequence analysis algorithms will be adapted to make optimal use of uncertainty information where it is available.

Anticipated Results/Potential Commercial Applications as described by the awardee: The result of this research will be a revision of software that is analytically robust with respect to uncertainties in DNA and protein sequences generally, and includes modules supporting (1) the estimation of these uncertainties from primary data, (2) the consistent management of uncertainty data through fragment assembly and experimental corroboration, and (3) the storage, display, reporting, and dissemination of uncertainty data. Expected benefits include better reliability of sequence data, longer reads with existing sequencing technologies, and more robust handling of sequencing errors and uncertainties by analytical software.

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Low Cost Automated Preparation of Plasmid, Cosmid, and Yeast DNA--MacConnell Research Corporation, 11408 Sorrento Valley Road, Suite 202, San Diego, CA 92121; (619) 452-2603
Dr. William P. MacConnell, Principal Investigator
Dr. William P. MacConnell, Business Official
DOE Grant No. DE-FG03-94ER81802
Amount: $75,000

A low cost, automated, benchtop instrument that can purify up to 24 samples of plasmid DNA simultaneously in one hour is now available. The instrument uses a form of agarose gel electrophoresis to separate the plasmid DNA and recovers it by electroelution into ~20 µl volume. The instrument has many advantages over other robotic and manual methods including the fact that it is twice as fast, at least six times less expensive, much smaller in size, easier to operate, lower in cost per sample, and it results in DNA pure enough for direct use in fluorescent automated sequencing. In addition, the instrument has only one moving part associated with its purification process and does not have internal reagent reservoirs. The instrument process begins with bacterial culture which can be loaded directly into a disposable sample cassette in the machine. Phase I will develop a more complex instrument using the above technology which will simultaneously process 192 (2 x 96) bacterial samples in 1.5 hours and allow the purification of both cosmid and genomic DNA from yeast and mammalian cells in quantities of 3 to 5 micrograms per cassette lane. The goal will be to obtain DNA of sufficient purity for direct use in automated fluorescent and manual sequencing as well as other molecular biology protocols.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned instrument and its disposables will be directly applicable to the molecular biology supply market consisting of over 25,000 laboratories groups in the US and nearly as many in Europe and Japan combined. Automated, cost effective, small-scale preparation of DNA is of central importance to most molecular biology researchers and to the Human Genome Project where reduction in the cost and man-hours of DNA sequencing is a major goal.

151

Pedigree Software for the Presentation of Human Genome Information for Genetic Education and Counseling--Molecular Machines, Inc., 2001 Wallace Avenue, Aptos, CA 95003; (408) 662-8706
Dr. Charles L. Manske, Principal Investigator
Mr. Timothy Popin, Business Official
DOE Grant No. DE-FG03-94ER81815
Amount: $75,000

The information generated by the Human Genome Project requires innovative displays if the information is to be widely utilized. This project involves the development of new algorithms for the efficient layout of pedigree diagrams to display genetic information for effective visualization of genetic relationships. These algorithms will be integrated with an interactive user interface for constructing pedigrees, setting attributes of individuals in pedigrees, and performing genetic calculations. Phase I will lay a foundation for integration of pedigree graphics with other data such as electrophoresis gel image analysis, cytogentic data, and chromosomal maps.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will develop algorithms and software to display genetic pedigrees whose elements are interactive icons associated with individuals. These icons will allow access to databases of genetic information for display or genetic calculations and will allow launching of other programs.

MEDICAL APPLICATIONS

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Growth of Lutetium Phosphate Scintillator Crystals for Positron Emission Tomography--ALEM Associates/Radiation Monitoring Devices, 303A Commonwealth Avenue, Boston, MA 02115; (617) 353-9581
Dr. Alexander Lempicki, Principal Investigator
Dr. Alexander Lempicki, Business Official
DOE Grant No. DE-FG02-94ER81702
Amount: $75,000

Positron emission tomography (PET) is a powerful new tool for radiographic imaging of human organs, particularly the brain. However, most presently known scintillator materials find their application limited by deficiencies in one or more of the desired characteristics: brightness, stopping power, speed, chemical stability, and cost. Thus, the full realization of the potential of this diagnostic tool requires the development of innovative scintillator materials that are faster, brighter, and more sensitive than any that are presently available. A new material system with great promise as a scintillation detector for PET applications has been discovered. This material, cerium-doped lutetium phosphate, offers a substantial improvement in performance over those now being used. It has high stopping power, superior light output, and rapid decay. Indeed, it is unique among currently known materials in combining superior performance in all important aspects for such application. Despite all these established advantages, however, one major development remains to be achieved before they can fulfill their destined role: a commercially viable method for fabrication. In Phase I the feasibility of applying either of two recognized technologies, Czochralski growth from the melt and traveling zone flux growth, to the practical fabrication of the requisite crystals will be assessed. Suitable specimens will then be evaluated optically, a fabrication method of choice identified, and the groundwork laid for full-scale exploitation in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project would develop a process for fabricating a demonstrably superior material into useful detector components, thereby generating a line of improved scintillators for PET applications. With a typical camera requiring thousands of crystals, it is clear that the new material could have a major commercial impact.

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Top-Seeded Solution Growth of Lutetium Phosphate from Potassium Pyrophosphate Flux--Deltronic Crystal Industries, Inc., 60 Harding Avenue, Dover, NJ 07801; (201) 361-2222
Mr. Robert Uhrin, Principal Investigator
Mr. Stuart Samuelson, Business Official
DOE Grant No. DE-FG05-94ER81737
Amount: $74,159

New detector materials are required for the design of new and improved positron emission tomography instruments that would offer higher resolution and better sensitivity in non-invasive medical applications. Currently, bismuth germanium oxide is one of the most popular scintillator materials because of its relatively good properties and low cost. Recently, cerium-doped lutetium orthophosphate (LOP) was shown to have exceptional promise as a scintillator material because of a light output twice that of bismuth germanium oxide and a decay time an order of magnitude shorter. Cerium-doped LOP crystals are currently produced by slowly cooling a molten solution which has an appreciable solubility for the scintillator material. Crystals produced by this method are large enough for determining fundamental properties but too small to efficiently fabricate detector crystals. A top-seeded solution growth method is planned in Phase I for producing cerium-doped LOP crystals commercially. The flux used to grow LOP crystals by slow cooling is based on lead pyrophosphate. While this material could be used to grow crystals by the top-seeded method, crucible cleaning is complicated by the necessity to dissolve the flux with strong acids. Furthermore, lead compounds have undesirable toxicological and environmental properties. Use of potassium pyrophosphate is planned as the solvent for growth of LOP by the top-seeded solution technique. This compound is very soluble in water and has a reduced toxicological and environmental sensitivity. Development of solubility data for molten solutions of LOP and potassium pyrophosphate should lead to the demonstration of feasibility for the top-seeded solution growth of this new scintillator crystal from a potassium pyrophosphate flux.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that the Phase I effort will establish the foundation for growth of high-quality single crystal LOP in a Phase II project by developing needed information on a suitable flux, solubility data, and demonstration of top-seeded solution growth. The availability of high-quality LOP crystals will lead to faster, more compact instruments for positron emission tomography. Additionally, this growth process could be used for growth of other rare earth orthophosphates for use in such applications as diode-pumped tunable lasers, optical isolators and high-power polarizers.

154

Low Field Magnetic Resonance Imaging with SQUIDs--Quantum Magnetics, Inc., 11578 Sorrento Valley Road, San Diego, CA 92121; (619) 481-4015
Dr. S. Kumar, Principal Investigator
Mr. John P. Sanders, Business Official
DOE Grant No. DE-FG03-94ER81839
Amount: $74,147

Superconducting quantum interference devices (SQUIDs) are the most sensitive magnetic field detectors in existence. Recent experiments have shown that SQUIDs can be used to detect radio frequency nuclear magnetic signals. This opens up the possibility of using SQUIDs to do magnetic resonance imaging (MRI), particularly at low fields. SQUID detection would make possible (1) increased image contrast using very low applied fields, (2) enhanced sensitivity for detecting non-hydrogen nuclei, (3) systems that operate at a wide range of frequencies, and (4) low cost systems using inexpensive low field magnets. SQUID MRI systems will be cost effective with conventional low T_c (critical temperature) SQUIDs, and will be even less expensive as good high T_c SQUIDs become available. In Phase I, a design for a prototype imaging system will be specified. Part of the Phase I effort will be to show that SQUIDs can be adapted to an imaging environment of changing fields and gradients.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned research will lead to the development of a superior MRI system, particularly at low fields, which will find wide use in medicine.

155

A Room Temperature, Low Noise Silicon Photodiode for Positron Emission Tomography--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Mr. Kanai S. Shah, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-94ER81844
Amount: $75,000

Positron emission tomography (PET) is a noninvasive medical imaging technique, which provides an image of a positron emitting radio pharmaceutical and its distribution in the body on a metabolic level. At the present time, the performance of this instrument is limited by the nuclear sensors used. Researchers have developed a promising dual detector concept for generating high resolution positron emission tomographs. In this concept, a photomultiplier tube coupled to several small scintillators is the primary detector for determining the time and the energy resolution of the interaction, while small photodiodes attached to the other face of each scintillator identify the crystal that scintillated. The depth of interaction is determined by combining the signals from both the photomultiplier tube (PMT) and the photodiode. The relatively high noise in conventional p-i-n photodiodes caused by their large capacitance is limiting the performance of this promising PET concept. The goal of the Phase I project is to develop new types of low capacitance silicon photodiodes which can operate with low noise at room temperature. If the project is successful, the use of these new photodiodes in the dual detector PET concept promises to be the breakthrough needed for the construction of new generation of high resolution PET imaging systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned sensor would have an enormous impact on the design of PET instruments. In addition, a high performance room temperature scintillation photodetector would find many other nuclear medicine applications. This detector could also have a variety of applications in physics research, industrial testing, and radiation safety.

156

Production of Carbon-11-Labeled Compounds for Positron Emission Tomography with a Low Energy Accelerator--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Ruth E. Shefer, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-94ER81854
Amount: $74,981

A new generation of economical, compact low energy accelerators have recently become available for the production of radioisotopes for positron emission tomography (PET). This project addresses the need for a carbon-11 (^{11}C) production target and radiochemical synthesis system for use with these new accelerators. ^{11}C-labeled biological molecules are used in a wide variety of important PET applications, including the study of receptor-based systems in the brain and heart, oxidative metabolism in tissue, and glucose metabolism. ^{11}C targets currently used with PET cyclotrons are not suitable for use at low bombarding energy. In Phase I, a new technique for the production of ^{11}C in a solid target via the $^{11}B(p,n)^{11}C$ nuclear reaction will be investigated. The goal of Phase I will be to develop an automated target design that provides $^{11}CO_2$ in clinically useful quantities, with high radiochemical purity, and with sufficiently high specific activity for the labeling of receptor ligands as well as acetate and glucose. In Phase II, we will couple this target to automated radiochemistry systems for conversion of the extracted activity to ^{11}C-radiopharmaceuticals commonly used in research and clinical PET studies.

Anticipated Results/Potential Commercial Applications as described by the awardee: The ^{11}C production target and chemical synthesis system developed in this program will allow the reliable, automated production of ^{11}C-radiopharmaceuticals with the new generation of economical, low energy accelerators for PET. The commercial availability of this system will speed the development of protocols for patient diagnosis and treatment monitoring with ^{11}C PET and will increase cost-effectiveness of PET in clinical practice.

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X-Ray Cadmium-Zinc-Telluride Focal Plane Arrays for Medical Imaging--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Rengarajan Sudharsanan, Principal Investigator
Mr. Patrick N. McDonnell, Business Official
DOE Grant No. DE-FG02-94ER81904
Amount: $74,951

A new cadmium-zinc-telluride (Cd(Zn)Te) linear X-ray focal plane array for scanning and staring medical imaging applications is being studied. The design is based on Cd(Zn)Te photodiodes, fabricated using metalorganic chemical vapor deposition (MOCVD) and advanced array processing technology. These focal plane arrays offer advantages of higher spatial and energy resolution and better sensitivity than conventional film-phosphor and scintillator-photodiode/ photomultiplier X-ray detectors. In addition, due to increased sensitivity of these detector arrays, the required X-ray dosage to patients can be reduced. Phase I will develop a small array of Cd(Zn)Te photodiodes. MOCVD will grow a Cd(Zn)Te epitaxial layer on one side and a mercury telluride (HgTe) layer on the other side of high resistivity Cd(Zn)Te. Titanium/aluminum layers will form a Schottky junction on the CdTe layer and HgTe will form an ohmic contact on the bulk Cd(Zn)Te. Arrays with 100 µm x 100 µm pixel size will be fabricated and tested for pixel-to-pixel uniformity. During Phase II, large arrays with smaller pixel size will be developed. In addition, a p-i-n device structure will be used to improve the performance of these detector arrays and commercialization of the technology will be pursued.

Anticipated Results/Potential Commercial Applications as described by the awardee: CdTe focal plane arrays with high spatial resolution and sensitivity will replace film-phosphor and scintillator-photodiode X-ray detectors in scanning medical imaging systems. In addition, these focal plane arrays can be used in X-ray astronomy, airport baggage scanners, and non-destructive testing.

PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

158

A Continuous Cryopump/Pellet-Fabrication Apparatus for Fusion--Cryogenic Applications F, Inc., 450 Bacon Springs Lane, Clinton, TN 37716; (615) 435-5433
Dr. Christopher A. Foster, Principal Investigator
Dr. Christopher A. Foster, Business Official
DOE Grant No. DE-FG05-94ER81734
Amount: $74,649

Fusion reactors based on the magnetic confinement of plasmas will require active fueling to replenish the deuterium/tritium escaping the plasma. Cryogenic pumps and frozen pellet injection are the most efficient means of pumping and refueling the tokamak plasma. Since the burn rate of the reactor is only a few percent, however, the exhaust fuel will have large quantities of unreacted deuterium and tritium. Since tritium is a radioactive gas it is important to limit the total tritium inventory of the reactor to a minimum. This will require rapid recycling of the tritium pumped from the reactor into the pellet fuel injection system. This project will accomplish this with a continuous cryogenic forepump which will receive the exhaust from the primary pumping system and produce high quality frozen deuterium/tritium pellets suitable for directly feeding a centrifuge pellet injector. The cryopump will thus be able to greatly reduce the tritium inventory by recycling the fuel back into the plasma within a few minutes from the time the fuel enters the pump. In addition the proposed pump/pellet fabrication apparatus consists of a single cryopanel which will both pump and produce pellets with no moving parts, thereby greatly increasing the reliability and reducing the cost of the apparatus as compared to conventional pumping and pellet fueling systems. In Phase I a small pump will be constructed which will demonstrate the capability of producing deuterium pellets, and a conceptual design of a full scale reactor system, to be constructed and tested as a Phase II effort, will be produced.

Anticipated Results / Potential Commercial Applications as described by the awardee: This work will lead to a practical cryogenic forepump which will produce frozen pellets of deuterium/ tritium. Such an apparatus will greatly simplify a fusion reactor fuel cycle and dramatically reduce the tritium inventory and therefore improve the passive safety of future commercial fusion reactors.

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Sapphire-Metal Joining for Low-Loss Gyrotron Windows--FM Technologies, Inc., 10529-B Braddock Road, Fairfax, VA 22032; (703) 425-5111
Dr. Richard Silberglitt, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG05-94ER81765
Amount: $74,983

A new technique, pulsed electron beam (PEB) joining, will be applied to the problem of joining low-loss ceramic materials used for windows in high frequency microwave devices to the metal vacuum envelope of the microwave device. The PEB technique allows selective heating of the specimen to be joined through preferential energy deposition that is controlled by a combination of the electron beam parameters and the properties of the specimen. Test specimens to be joined in Phase I will consist of sapphire plates and thin copper sheets. The microstructure of the test specimens will be examined using scanning electron microscopy, and comparisons will be made with expectations bases upon Monte Carlo computer simulations of the PEB energy deposition profile. The mechanical strength of the test specimens will then be evaluated using microindentation techniques. Based upon these data, joining parameters will be identified for Phase II test specimens that will allow determination of the properties of PEB-produced joints under conditions that simulate window designs for gyrotron oscillators.

Anticipated Results / Potential Commercial Applications as described by the awardee: High power gyrotrons are a critical component of electron cyclotron resonance heating, a preferred and promising heating method for magnetic fusion plasmas. The window is currently the single most serious mode of failure of high power gyrotrons in recent years. This project, if successful, will provide a method for attachment of low-loss windows in gyrotron oscillators with minimal residual stress, which will greatly increase window design flexibility.

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Economical and Reliable Niobium-Tin Conductors via Innovations in Stabilizers--IGC Advanced Superconductors, 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Hem C. Kanithi, Principal Investigator
Mr. B. A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81782
Amount: $75,000

High critical current densities (J_c) and low AC losses are being achieved in Nb_3Sn as a result of design and/or process innovations that came about over the last decade. The so-called internal tin approach which has been the choice of US industry, has emerged in many forms; each with a novelty to address one characteristic of the conductor or another. The general approach itself involves the manufacture of two major components - 1) a composite element and 2) a stabilizer tube. The latter provides relatively large amounts of copper desirable in the wire to add stability and protection to the final superconducting device. It has to incorporate diffusion barriers such as Nb, Ta, or V to keep the tin from polluting the copper during final heat treatment. In cases of pulsed field applications, it should not react with tin forming a continuous A15 superconducting layer. The present method of making the stabilizer member is by tubular hot extrusion. The geometry and ductility constraints placed on the diffusion barrier material are so demanding that over the years the stabilizer manufacturing process has become a very expensive and tedious one. In order to limit total strain from billet to final wire, the stabilizer billet diameter and the restack bundle size have been reduced raising the cost materials. Since the stabilizer is a critical component both in terms of product performance and cost, IGC Advanced Superconductors proposes a program to develop reliable and significantly economical Nb_3Sn conductors by improving stabilizers. The feasibility of producing stabilizers by hot isostatic pressing (HIP), totally circumventing extrusion will be studied in Phase I. Barrier materials-Nb, Ta, and a combination of the two will be incorporated in small stabilizers which will be further tested by co-drawing with composite materials. Mechanical and material design details and HIP parameters that are optimal will be investigated. Following the success of Phase I effort, scaled-up designs and cost details for large quantity production will be addressed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The intended result of this research is the development of an economical high-rate production process for Nb_3Sn based superconductors. Simplifying the manufacturing method for stabilizers used in these conductors should increase their reliability in any device application. It is expected that a third of the present internal-tin costs can be eliminated. Applications that could benefit include magnets for fusion, future High Energy Physics accelerators, high frequency NMR spectroscopy and possibly, cryogenless MRI scanners for medical diagnostics.

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Improvement in the Loss and Critical Current Density Properties of Internal-Tin Niobium-Tin--IGC Advanced Superconductors, 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. B. A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81783
Amount: $75,000

The aim of this work is to further improve the properties of internal-tin niobium-tin (Nb_3Sn) strands for fusion applications. A conductor has been developed which meets all the HP-1 International Thermonuclear Experimental Reactor (ITER) specifications. In this project losses will be further lowered by reducing the "bridging" that occurs between neighboring filaments. In Phase I the effects of various heat treatments and tin concentrations on the critical current (J_c) and loss properties will be examined. The loss properties of the individual subelements will be compared with those of the 19 subelement assemblies at different sizes, in order to determine the absolute spacing below which coupling occurs between the first and second row of filaments and also the effects of distortion. In Phase II the data obtained in Phase I will be used to design a subelement strand and an ideal restack array for low loss, high J_c operation.

Anticipated Results / Potential Commercial Applications as described by the awardee: This work should result in the development of an improved, low loss Nb_3Sn material for magnets to be used in high field pulsed or high ramp rate applications. At the present time, most of the demanding requirements arise in the fusion area. One such possible application would be the inner windings of the ITER central solenoid coil.

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ANSAT - An Antenna Sheath Analysis Tool--Lodestar Research Corporation, 2400 Central Avenue, P-5, Boulder, CO 80301; (303) 449-9691
Dr. James R. Myra, Principal Investigator
Dr. Richard E. Aamodt, Business Official
DOE Grant No. DE-FG05-94ER81799
Amount: $75,000

The goal of the Phase I research is to develop a preliminary version of antenna sheath analysis tool (ANSAT), a post-processor for the ARGUS code. ARGUS is an existing full wave electromagnetic code which can be used to determine the electromagnetic fields produced by ICRF (ion cyclotron range of frequencies) antennas in the context of ion-cyclotron heating of fusion plasmas. The ANSAT code will use the output from ARGUS to calculate radio frequency (rf)-sheath driving voltages on the Faraday shield of an antenna. In Phase I, critical aspects of the physics and code development will be examined in order to assess the prospects for developing a complete sheath analysis tool in Phase II. A preliminary version of the code will be developed in Phase I to show how the rf sheaths driving voltages can be calculated and employed to assess the strengths and weaknesses of an antenna design with respect to critical voltage handling and edge plasma interaction issues. These issues include hot spots on the screen, weak points with regard to breakdown, ICRF-convective cells, power dissipated in the sheaths, and the influx of impurities resulting from rf-driven sputtering processes at the Faraday shield.

Anticipated Results / Potential Commercial Applications as described by the awardee: If successful, the Phases I to III research and development projects will result in a user friendly post-processing code or suite of codes that will support the design of ICRF antennas operating in fusion plasmas. The codes will provide a unique capability to assess antenna designs for important sheath related phenomena to a degree that is not presently available. Antenna designs will be an important part of upcoming plans for both the Tokomak Physics Experiment (TPX) and International Thermonuclear Experimental Reactor (ITER) tokamaks, as well as possibly IGNITOR, Wendelstein VII-X, and Faraday screenless operation on Joint European Torus (JET). The availability of a sheath antenna design tool will be both timely and marketable to the Federal Government and/or the joint central team of ITER, as well as to the European and possible the Japanese fusion communities.

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An Innovative Technique to Bond One Dimensional Carbon-Carbon Composites to Dispersion Strengthened Copper--Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706; (602) 574-1980
Dr. S. Guha, Principal Investigator
Dr. R. O. Loutfy, Business Official
DOE Grant No. DE-FG02-94ER81804
Amount: $75,000

One dimensional carbon-carbon (C-C) composites are considered as candidate tile materials for diverter applications due to their high thermal conductivity. Unfortunately, such composites also suffer from extremely poor cross-fiber tensile strength. The problem of bonding dispersive strengthened copper (Cu) tube, with and without soft oxygen-free high conductivity (OFHC) Cu interlayers, has been analyzed by researchers elsewhere who concluded that, although OFHC Cu layers were beneficial in reducing the stresses, the magnitude of stresses in the C-C composite was still high enough to crack the C-C composite. By contrast, an innovative solution is suggested which will eliminate the coefficient of thermal expansion (CTE) mismatch in the cross-fiber direction and simultaneously reduce the CTE mismatch along the length of the fiber. This is expected to reduce the stresses in the C-C composite to the point that they are below the failure strength of the composite. An attendant benefit of this approach is that the thermal conductivity of the tube will also be increased. The feasibility of this concept will be investigated in Phase I by using numerical analysis and a unique composite processing technique.

Anticipated Results/Potential Commercial Applications as described by the awardee: In addition to being directly useful to fusion reactor research, which could supply the nation with a source of cheap energy in the future, other potential applications for this technology would be in the automobile and aerospace industries where joining of dissimilar materials such as ceramics to metals and composites is desired.

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A Multi-Megawatt Millimeter-Wave Source for Plasma Heating and Control--Omega-P, Inc., 2008 Yale Station, New Haven, CT 06520; (203) 458-1144
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG05-94ER81823
Amount: $75,000

This project is investigating the feasibility of gyro-harmonic conversion using a spatiotemporally modulated electron beam for efficient generation of multi-megawatt millimeter wavelength radiation for electron cyclotron resonance heating (ECRH) plasma heating and control. Feasibility hinges on demonstration of reasonable high harmonic conversion efficiency and suppression of competing modes. Previous theoretical work has shown high efficient fifth harmonic conversion at 94 GHz, producing megawatt-level power. The nonlinear analysis and particle simulations will be extended to 13th and higher harmonics during Phase I to obtain the design parameters of a harmonic converter for the production of power at 140 GHz and above using an X-band (8 to 12 GHz) rf driver. Methods to inhibit power flow to competing converter modes will be explored. Successful results of the Phase I study are expected to lead to designs for proof-of-principle experiments to be carried out during Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful Phase I designs and Phase II proof-of-principle experiments can establish an alternative to the gyrotron for millimeter-wave ECRH. Other commercial applications for such a source exist in materials processing, waste disposal, and advanced particle accelerators.

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Advanced Low-Stress Brazing of Plasma-Facing Fusion Components with High Energy Electron Beams--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Daniel L. Goodman, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-94ER81857
Amount: $73,994

The use of high energy (E ~ 2 to 19 MeV) electron beams (HEEB) at high average power (P ~ 50 kW to 1 MW) allows compression annealed pyrolytic graphite (CAPG) and carbon-carbon (CC) composite components to be joined to metallic substrates without the high residual stresses that accompany conventional brazing. Reliable brazing of CAPG and CC to copper alloys is necessary to fabricate plasma limiters and diverters for use in a next large fusion reactor. HEEB joining utilizes deep-penetration volumetric heating to preferentially melt a thin, high-Z braze alloy interlayer. The localized power deposition raises the graphite and interlayer temperatures without heating of the metallic substrate. The process eliminates the substrate cooling step and the residual stresses and braze failures caused by thermal expansion mismatch. HEEB brazing with induction linacs is a high-throughput process, which will allow fabrication of a diverter composed of hundreds of thousands of tiles at low unit cost. A new generation of pulsed induction linear accelerators has been developed which allow reliable, cost efficient production of high average power electron beams with the necessary parameters for carbon brazing. A unique feature of these accelerators is the high repetition rate (>5000 pps) all-solid-state pulsed power drivers which make these accelerators scalable to MW power levels at an electron beam cost of $2 to 3/Watt. The induction accelerator technology is consistent with the power densities (1 to 5 kW/cm^2) and beam energies (2 to 10 MeV) required for low-stress brazing. Preliminary experiments in Phase I will demonstrate low-stress joining and determine joint properties. Process optimization and the fabrication of graphite and CC first-wall limiter prototypes are planned for Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: In addition to the fusion reactor application, the ability to reliably braze graphites and carbon-carbon composites to metals is needed for high, medium, and low temperature commercial applications. High temperature (>1000°C) applications include engine components and heat exchangers for advanced vehicles (National Air Space Plane, High Speed Civilian Transport). Aerospace structures and heat dissipative planes in electronic components could also benefit from this technology.

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Ductile Joining of Beryllium to Copper--Surmet Corporation, 33 B Street, Burlington, MA 01803; (617) 272-3250
Dr. Suri A. Sastri, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-94ER81875
Amount: $75,000

Beryllium appears to be the choice for plasma facing components of the high energy fusion reactor International Experimental Thermnuclear Reactor (ITER) design. Current design heat flux conditions for the ITER are formidable and must be dealt with safely and reliably. Components such as the divertor, as well as others, must be actively cooled. This requirement makes the development of successful methods for joining of beryllium to copper a critical issue in the fusion reactor development programs. Even though various approaches have been advanced for the joining of beryllium to itself and to other metals, the joining technology currently available cannot be used in view of the special requirements imposed by the fusion reactor environment. Beryllium is an extremely reactive metal and forms brittle intermetallic compounds when in metallurgical contact with most metals. There is also the high reactivity with oxygen resulting in the development of a tenacious oxide skin that makes wetting or diffusion bonding very difficult without extremely careful surface preparation techniques. The need for a ductile joint in the case of brazing beryllium cannot be over emphasized. An innovative surface treatment procedure for beryllium is planned that will facilitate its brazing to copper using braze alloys with either high or low melting temperatures. The technique involves considerations of metallurgical compatibility and thin film diffusion barrier concepts.

Anticipated Results/Potential Commercial Applications as described by the awardee: Beryllium is an extremely important structural material with unique properties. The modulus to density ratio of beryllium is at least six times higher than common high performance engineering materials. The ability to successfully braze join beryllium without embrittlement is important not only for the fusion reactor application but also in the fabrication of lightweight and exceptionally stiff components for aerospace applications.

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Joining of Aluminum to Carbon-Carbon Composites for Fusion Reactor Applications--Surmet Corporation, 33 B Street, Burlington, MA 01803; (617) 272-3250
Dr. Suri A. Sastri, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-94ER81877
Amount: $75,000

The joining technologies currently available for joining metals to carbon-carbon (C-C) composites are not entirely satisfactory for fusion reactor applications for many reasons. Active braze alloys containing reactive metals that wet the carbon by forming carbides have been the accepted method used commonly to make braze joints on C-C and graphites. Such use of active braze alloys which contain strong carbide formers often results in the tendency to produce weak joints with braze metal flowing to places not desired and yet not going to places where it is needed. The problem of joining C-C to aluminum (Al) metal is especially difficult because of the low melting point of Al, 660°C, and the large difference in coefficient of thermal expansion between Al and C-C composites. A high purity version of the low melting eutectic alloy of Al and ~12 wt. % silicon, melting near 600°C can be used to join Al, but it is not compatible with C-C materials. In Phase I the feasibility of successfully braze joining C-C test coupons to Al for fusion reactor applications will be evaluated by using a special surface preparation and infiltration technique that replaces the C-C surface with a copper surface which then can be brazed to Al.

Anticipated Results/Potential Commercial Applications as described by the awardee: Joining of C-C to metals is an issue that impacts not only fusion programs but also many advanced materials programs currently sponsored at the national laboratories and in industry. Companies that produce C-C composites have expressed an interest in this technology. The successful development of this novel braze technology for C-C should open a host of new applications for this important material.

FUSION ENERGY SYSTEMS

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A Feasibility Study to Correlate Vanadium (Chromium, Titanium) Alloy Weld Strength with Weld Chemistry--Charles Evans and Associates, 301 Chesapeake Drive, Redwood City, CA 94063; (415) 369-4567
Mr. Charles J. Hitzman, Principal Investigator
Mr. James E. Plank, Business Official
DOE Grant No. DE-FG03-94ER81726
Amount: $74,910

Vanadium (V) alloys are prime candidate materials for first wall and blanket structures in fusion reactors. However, V welds are often embrittled by the incorporation of oxygen (O), nitrogen (N), and hydrogen (H) into the weld structure. This Phase I research will determine the feasibility of correlating O, N, and H concentrations in V alloy welds with weld strength. Welds in V (chromium (Cr), titanium (Ti)) alloys will be evaluated in this feasibility research, and gas-tungsten arc welds will be prepared in different O, N, and H gas environments in order to produce a large sampling of possible weld chemistries. Hardness and tensile elongation tests will be performed on sets of welds produced under approximately 10 weld conditions. Chemical analysis of these different welds will be performed using state-of-the-art materials analysis techniques such as secondary ion mass spectrometry (SIMS), Auger electron spectroscopy (AES) and scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS). These three techniques combine high elemental detection sensitivity (SIMS) with high spatial resolution analysis (AES). In addition, SEM/EDS can produce rapid elemental surveys of a sample surface. SIMS analyses of weld cross-sections will determine the concentration range of O, N, and H contaminants. If O and N are present at sufficiently high concentration (~1% atomic), AES and SEM/EDS analyses will be performed to determine quantitative O and N concentrations. SIMS analyses will be performed, and the intensity, lateral, and in-depth distribution of these contaminants will be measured. SIMS relative ion intensities, e.g. O^-/V^-, N^-/V^- and H^-/V^-, will be evaluated and correlations between these relative intensities and the weld strength determined. Techniques such as pattern recognition and neural networks will also be applied to these data to produce correlations between more complex sets of variables. Ion implant standards of ^{18}O, ^{15}N and ^{2}H will be prepared in order to assess the quantitative capabilities of SIMS in analysis of this metal alloy system. This research will lead to a better definition of the chemistry of V(Cr,Ti) welds and the importance of O, N, and H to weld strength. The Phase I results will determine the approximate levels of O, N, and H introduced for a range of weld conditions, and these data will set the necessary detection sensitivity for innovative, non-destructive weld integrity monitors.

Anticipated Results/Potential Commercial Applications as described by the awardee: The analytical results produced from Phases I and II will determine the pertinent correlations between V alloy weld strength and the chemical composition of the weld. Phase II will also explore methods of non-destructively testing the chemistry of these welds. This Phase II result could lead to routine methods of preparing strong, non-brittle welds in V alloys used in nuclear fusion applications. This development will provide better methods of constructing future fusion reactors. In addition, this research could produce a non-destructive, transportable weld tester which is sensitive to O, N, and possible H concentration in welds.

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A Multilayer Silicon Carbide Fiber Coating for Toughened, Neutron Radiation-Resistant Silicon Carbide/Silicon Carbide Composites--
Hyper-Therm, Inc., 18411 Gothard Street, Units B & C, Huntington Beach, CA 92648; (714) 375-4085
Dr. Robert J. Shinavski, Principal Investigator
Mr. Wayne S. Steffier, Business Official
DOE Grant No. DE-FG03-94ER81778
Amount: $72,057

Silicon carbide (SiC) has been identified as a promising material for fusion energy applications because of its low activation, low decay heat, and outstanding high-temperature mechanical properties. Continuous SiC fiber-reinforced SiC-matrix composites (SiC/SiC) are of particular interest because of their relatively high strength and toughness compared to that of monolithic SiC. Currently available fiber coatings such as carbon and boron nitride have demonstrated the desired mechanical characteristics necessary to promote high composite strength and toughness. However, the utility of these materials is severely limited by their susceptibility to mechanical degradation when exposed to neutron irradiation. This limitation is due to the dimensional and microstructural instability of the fiber coating as a result of radiation exposure. SiC/SiC composites exhibiting high tensile strength and fracture toughness were developed incorporating an engineered SiC fiber coating system. By methods of chemical vapor infiltration (CVI), SiC/SiC composites, toughened by an unbonded multilayer SiC fiber coating, were produced and evaluated. Comparison of the tensile test results was made with that of a baseline state-of-the-art SiC/SiC composite system employing an optimized pyrolytic carbon (PyC) fiber coating. Results indicate that the multilayer SiC fiber coating emulates the desirable mechanical attributes of PyC necessary to impart high composite strength and toughness, and may possess the desired properties for increased neutron radiation resistance. The objective of this Phase I project is to investigate the feasibility of optimizing the multilayer SiC fiber coating system so as to maximize the strength and toughness of SiC/SiC composites for potential fusion energy applications. Optimization will consist of evaluating the effect of the number of unbonded, uniform thickness SiC layers in the multilayer fiber coating systems. Five CVI-densified SiC/SiC composite plates incorporating one, two, four, eight, and sixteen unbonded SiC layers in their respective multilayer fiber coating systems will be produced and evaluated to determine their corresponding tensile strength and fracture toughness characteristics. An SiC/SiC composite utilizing one of the recently developed low oxygen content or stoichiometric polycrystalline SiC fibers will be produced incorporating the optimum multilayer SiC fiber coating system and evaluated to determine its durability/survivability characteristics in a neutron irradiation environment.

Anticipated Results/Potential Commercial Applications as described by the awardee: SiC-matrix composites are an enabling class of materials for first wall plasma containment, liner, and diverter components in fusion energy systems, stationary turbine and power generation components, radiant burner and heat exchanger tubes, and for a variety of thermostructural applications in aerospace propulsion combustors and nozzles, hypersonic airframe thermal protection systems, and spacecraft re-entry heatshields.

PLASMA DIAGNOSTICS

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An Improved Heavy Ion Beam Detector for Plasma Systems--InterScience, Inc., 105 Jordan Road, Troy, NY 12180; (518) 283-7500
Dr. Jeffrey Beckstead, Principal Investigator
Dr. James T. Woo, Business Official
DOE Grant No. DE-FG02-94ER81788
Amount: $74,793

Particle beams are commonly used for plasma diagnostics to obtain time and spatially resolved measurements of density, temperature, and space charge potential. An important application is in controlled fusion research where fluctuations in these quantities are known to have an important effect on adequate confinement of the thermonuclear plasma to realize net power output. During the last few years, beam probe measurement on experiments such as the original Texas Experimental Tokamak (TEXT) have concentrated on the characterization of the interior fluctuations, and large discrepancies still exist between theoretical predictions and experimental measurements by a variety of techniques. There is, therefore, a need for more definitive experimental measurements. To date, only two-point correlation techniques have been used on the beam probe data. The result is that only the mean wave-number, k, and the spectral width, σ_k, of the turbulence distribution, $S(k,\omega)$, can be determined; no information can be extracted on other features of the spectrum. By extending the range and number of sample volumes simultaneously recorded, a better understanding of the low-k turbulence measured by the beam probe can be achieved. This can be accomplished by placing an array of beam detectors near the plasma edge. However, to obtain the accuracy required for density fluctuations in tokamak experiments, the detectors must be sensitive to 0.1% or better in the harsh environment near the plasma edge. These measurements will provide a better understanding of tokamak plasma equilibrium, stability, and transport. Phase I will be a feasibility and optimization design study for a high-energy ion beam detector that can provide this accuracy.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful development of the detector would find widespread use in research and commercial areas. When incorporated into current heavy beam probe diagnostics, the detector arrays will result in a better understanding of the physics governing the transport processes in magnetically confined plasmas. Outside the fusion community, the detector system can be used to diagnose plasma-aided manufacturing devices where edge detectors experience high radiation exposures. In addition, high resolution detectors are required in ion implantation systems used in the microelectronics industry.

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A Rutherford Scattering Diagnostic for Ion Dynamics in Magnetically Confined Fusion--Omega-P, Inc., 2008 Yale Station, New Haven, CT 06520; (203) 458-1144
Dr. Michael A. LaPointe, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG05-94ER81822
Amount: $75,000

The objective of this project is to study the feasibility of using Rutherford Scattering to measure ion dynamics in a magnetically confined plasma. The scattering process to be studied would utilize a neutral helium beam to scatter off the majority ions in the plasma. The scattered beam distribution provides measurement of the equilibrium ion density, temperature and flow velocity, and fluctuations of the above three qualities. The diagnostic neutral beam injector to be studied would be based on proven designs utilized at the Institute for Nuclear Physics in Novosibirsk, Russia. Designs for a multi-channel neutral particle analyzer to detect the scattered beam will also be studied.

Anticipated Results/Potential Commercial Applications as described by the awardee: A successful Phase I study would allow design specifications and costs to be determined for utilizing Rutherford scattering to directly measure ion dynamics of fusion relevant plasmas. Potential applications are monitoring and feedback control input for large magnetic fusion devices and eventual fusion reactors, and as a species and temperature monitor for plasma based incinerators.

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A Novel Miniature Optical Chopper for Deuterium-Tritium Plasma Diagnostics--PXL, Inc., 1 - H Deer Park Drive, Monmouth Junction, NJ 08852; (908) 329-0505
Dr. Leonid Y. Polonski, Principal Investigator
Dr. Ada Suckewer, Business Official
DOE Grant No. DE-FG05-94ER81837
Amount: $73,531

This project will develop a novel miniature optical chopper to enable fiberoptically coupled signals to be distinguished from radioluminescence generated in the fiber in a harsh radiation environment. Fiberoptics are in widespread use in fusion facilities to transmit optical signals from plasmas to remote detectors that are shielded from radiation. However, the fibers are not radiation immune. Luminescence and radiation induced loss of transmission have been measured in optical fibers even at the comparatively low neutron level of present deuterium-deuterium plasmas. In deuterium-tritium plasmas, radiation effects will be two orders of magnitude higher. The planned device will enable the subtraction of radiation induced luminescence from the optical signal originating from the plasma. The device is especially suited to the restricted access and high magnetic field environment of tokamaks. The Phase I project will construct and test a prototype device. In Phase II it will be installed and optimized in a tokamak environment.

Anticipated Results/Potential Commercial Applications as described by the awardee: The work will result in the development of a compact and inexpensive optical chopper that will enable radioluminescence, generated in optical fibers in a harsh radiation environment, to be subtracted from signals carried by the fibers. By facilitating fiberoptically coupled diagnostics in high radiation environment, the device will aid in the development of commercial fusion power. It will also be ideally suitable as an inexpensive and more effective alternative to motor-driven chopper wheels for phase-locked detection of fiberoptically coupled signals.

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An X-Ray Beam Deflector for High Resolution Spectroscopy of Fusion Plasmas--Radiation Science, Inc., P.O Box 293, Belmont, MA 02178; (617) 621-7076
Dr. Allen S. Krieger, Principal Investigator
Dr. Allen S. Krieger, Business Official
DOE Grant No. DE-FG02-94ER81845
Amount: $75,000

Small quantities of krypton will be injected into the International Thermonuclear Experimental Reactor (ITER) as a means of radiatively cooling the edge of the plasma in order to protect the components exposed to the plasma. The krypton will be ionized to the helium-like stage under the conditions expected at the core of the ITER plasma. High resolution X-ray spectroscopy of the K lines of helium-like krypton has been suggested as a means of measuring the central ion temperature of ITER. This project will construct an X-ray optical system that will deflect the 13 keV krypton K X-rays toward the aperture of a shielded high resolution X-ray spectrometer while the paths of neutrons, gamma rays, and X-rays of other energies travel in a straight line toward an absorber. This optical system will improve the signal to noise ratio of the high resolution spectrometer in two ways. It will keep background radiation away from the position sensitive X-ray detector, and it will eliminate 6.5 keV continuum X-rays which would otherwise be diffracted in first order to overlap the krypton X-ray lines. During Phase I, the requirements for the krypton X-ray beam deflector, will be established, a preliminary design concept for the beam deflector will be developed, and the X-ray optical elements will be specified and modeled in order to estimate the improvement to be expected with this system. This information will be available in time for critical design decisions concerning ITER diagnostics. In Phase II, we will build an engineering verification prototype beam deflection system for installation at the Tokamak Physics Experiment (TPX).

Anticipated Results/Potential Commercial Applications as described by the awardee: This optical system will improve the signal to noise ratio of the high resolution krypton line spectrometer, making it possible to determine the ion temperature at the core of ITER by Doppler broadening measurements. The technique developed for this project will demonstrate that it is possible to manipulate hard x-ray beams, and deflect them through large angles. The deflection of broad band x-ray beams will have immediate application to the shielding of other x-ray instruments exposed to adverse radiation environments. It should also find applications in synchrotron radiation research, X-ray astronomy, and ultimately in commercial X-ray technology.

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In-Situ Annealing of Radiation Damage of Optical Components in Tokamak Diagnostics--
Rockford Technology Associates, Inc., 501 South Sixth Street, Professional Arts Building, Champaign, IL 61820-5579; (217) 359-3569
Mr. Erlan G. Batyrbekov, Principal Investigator
Mr. John W. Tompkins, Business Official
DOE Grant No. DE-FG02-94ER81849
Amount: $74,999

The harsh radiation environment presented by the D-T burning plasma in next-step tokamak fusion devices can cause severe damage to critical optical components used in research diagnostics and control instrumentation. The technical objective of Phase I is to determine the feasibility of using combined thermal/optical annealing techniques to maintain the optical quality of these components. Experimental studies, using a TRIGA research reactor to simulate the radiation environment expected in fusion devices, will determine the techniques and frequency required to carry out such annealing. The goal is to find ways to perform annealing remotely while the fusion device continues operation. This will require periodic shut-down of diagnosis channels during annealing. However, by using a well-planned schedule for the annealing and incorporating redundant channels where required, the basic diagnostics needed for safe operation could be maintained at all times. Phase I will study annealing methods for representative samples of silica and ion implanted cesium iodide. These test materials are selected for relatively good resistance to radiation damage, based on data from past studies. The experimental program would then involve a test matrix, consisting of the two samples, combined with studies of the three annealing methods (thermal, optical, and combined), and three different annealing frequencies (i.e., the interval between annealing). Issues to be resolved include the optimal conditions (temperatures, light intensities, etc.), the duration of the annealing step, the interval between annealing treatments necessary to maintain desired transmission limits, and the effects of repeated annealing on the materials. If the feasibility of this approach is established in Phase I, studies in Phase II will be designed to develop the appropriate annealing capability for optical components in specific diagnostics for next-step fusion devices, such as the International Thermonuclear Experimental Reactor and the subsequent "demo" reactor.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that special techniques can be developed so that periodic annealing can maintain good transmission characteristics of optical materials exposed to a harsh radiation environment. This will enable the design of dependable, accurate diagnostics for fusion reactors. Other important uses include radiation hardening of "final optics" for inertial confinement fusion utilizing laser drivers, space satellite windows, solar cells, and fission reactor instrumentation. Manufacture of integrated optical/annealing units for these various applications represents a potentially significant market opportunity.

TECHNOLOGY AND INSTRUMENTATION FOR HEAVY ION FUSION ACCELERATORS

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A High-Charge-State Heavy-Ion Source--Duly Research, Inc., 1912 MacArthur Street, Rancho Palos Verdes, CA 90732; (310) 548-7123
Dr. Shmuel Eylon, Principal Investigator
Dr. David U. L. Yu, Business Official
DOE Grant No. DE-FG03-94ER81741
Amount: $74,572

The goal of this project is the development of a heavy ion stripping technique to achieve a high charge state beam. The ion stripper proposed here could be added to existing single charge state, low emittance, high brightness ion sources. Using high charge state beams in a driver for heavy ion fusion can increase the acceleration efficiency, leading to a reduction in the driver accelerator size and cost. Several ion stripping techniques, based on the ionization of an energetic ion beam colliding with charged particle beams (electrons, ions), photon beams (lasers), and a quiescent neutral gas have been evaluated. Upon evaluation and comparison with other techniques, the neutral gas technique was selected because of its simplicity and low cost. Phase I is a feasibility study and performance evaluation of a neutral gas ion stripper technique. A neutral gas slit stripper will be designed and tested on the Lawrence Berkeley Laboratory 2MeV, 0.8A K^+ ion beam injector. Stripper parameters, including dimensions, gas, gas pressure, and beam parameters, including charge state distributions (stripping efficiency) and beam quality (transverse emittance) will be analyzed, verified experimentally, and optimized.

Anticipated Results/Potential Commercial Applications as described by the awardee: Results of the Phase I feasibility investigation, which examines ion stripping in a very small fraction of the ion beam, will provide design and testing criteria for the full-beam investigation in Phase II. It is anticipated that the heavy ion fusion driver-scale, high charge state ion source will provide a significant contribution to the heavy ion fusion accelerator research DOE national program. The concept of using an accelerator with a higher charge state beam will lead to a significant saving in the length and cost of the driver accelerator in a heavy ion fusion energy plant.

NUCLEAR AND HIGH ENERGY PHYSICS EDUCATIONAL DEVICES

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A Unique Educational Game with Interactive Tutorials for Learning about Accelerators, Detectors, and Particle Physics--G. H. Gillespie Associates, Inc., P.O. Box 2961, Del Mar, CA 92014; (619) 677-0076
Dr. George H. Gillespie, Principal Investigator
Dr. George H. Gillespie, Business Official
DOE Grant No. DE-FG03-94ER81768
Amount: $74,940

An innovative multimedia game will be developed to introduce precollege students to the world of particle accelerators, particle detectors, and nuclear and elementary particle physics. The concept is a fast-moving game in which each player rides with a group of subatomic particles through the interior of an accelerator. The game illustrates the motion of charged particles in electric and magnetic fields, simple harmonic oscillations, repulsive forces between particles with the same charge, and other fundamental physics concepts. Ultimately, as his or her beam hits its intended target, a spectrum of particles is created and the player is introduced to the elementary particles and the fundamental forces of nature. At different stages of the game, obstacles are introduced which the player must overcome, if the beam is to be successfully accelerated with adequate intensity to produce the collision event rate needed to discover a new elementary particle. The game ends with graphic exploding images of the collision events that the student's beam produces. The nuclear and elementary particles that his or her play has created, and the detector technology used to observe them, are introduced. Videos and tutorials offer the student further information avenues. A prototype of the game will be developed, including examples of several types of interactive tutorials, during Phase I. The effectiveness of the concept as a teaching aid will be evaluated by integrating the prototype game with the classroom instruction of a physics course at the high school level.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project provides an innovative and unique new approach to support secondary physics education. Precollege students will have an exciting tool with which to learn about the world of accelerators, detectors, and nuclear and particle physics in a self-paced, interactive and entertaining environment.

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The Particle Beam Optics Interactive Computer Laboratory--G. H. Gillespie Associates, Inc., P.O. Box 2961, Del Mar, CA 92014; (619) 677-0076
Dr. George H. Gillespie, Principal Investigator
Dr. George H. Gillespie, Business Official
DOE Grant No. DE-FG03-94ER81767
Amount: $75,000

The Particle Beam Optics Interactive Computer Laboratory is a new and unique educational tool for demonstrating the physics of charged particle beams and charged particle beam optical systems. Self-paced interactive tutorials offer insight into both the principles of particle optics and the technology used in particle optics beamlines. A complete computational capability is incorporated to assist students in designing and analyzing their own particle optics systems. The Laboratory is composed of four key elements. The first is a graphical user interface shell that provides for a highly interactive learning session. The second is a knowledge database containing information on electric and magnetic optics transport elements. The knowledge database provides interactive tutorials on the fundamental physics of charged particle optics and on the technology used in particle optics hardware. The third element is a graphical construction kit that provides tools for students to interactively and visually construct optical beamlines. The final element is a charged particle optics computational engine that computes trajectories, transports beam envelopes, and carries out similar calculations for the student designed beamlines. A modular software environment will be used for the Laboratory and during Phase I prototype modules will be written that provide examples for each cf the key elements.

Anticipated Results/Potential Commercial Applications as described by the awardee: The Particle Beam Optics Interactive Computer Laboratory will provide universities and colleges with a powerful new software tool for teaching particle beam optics. Interactive tutorials and a graphical beamline construction kit are combined with an established charged particle optics computational engine to produce an innovative, self-paced education aid.

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A Multimedia Software Tutorial on Superconducting Accelerator Magnets--MJB Consulting, 1415 Country Ridge Drive, DeSoto, TX 75115; (214) 709-1957
Dr. Millicent Ball, Principal Investigator
Dr. Millicent Ball, Business Official
DOE Grant No. DE-FG05-94ER81813
Amount: $74,959

Completion of this project will provide a multimedia software tutorial introduction to the physics and engineering concepts of superconducting magnets for high energy physics accelerators. The presentation of the material will make full use of the latest computer technology for hypertext, interactive, multimedia presentations, including video footage, sound, graphics, and animation. The target level for the tutorial is junior or senior level undergraduates. Phase I effort focuses on the design and feasibility study. The tutorial content will be developed and relevant video footage, photographs, or other material from the superconducting magnet research programs at the national laboratories will be located. Software for implementing hypertext presentations, computer animation, and interactive graphics will be evaluated. Sources and procedures for transfer of video footage to CD-ROM disks will be surveyed. Preliminary contacts will be made with undergraduate physics or engineering departments and Internet sites to locate potential test sites for Phase II. Phase II will consist of implementation and testing of CD-ROM and Internet versions. In Phase III, the tutorial will be distributed on CD-ROM disks and Internet, for use by colleges or any interested computer users.

Anticipated Results/Potential Commercial Applications as described by the awardee: This tutorial is designed to relate undergraduate engineering and physics course work to current challenging technical research in the design of superconducting magnets for high energy physics accelerators, but it will also be useable by members of the general public who have interest in scientific subjects. The presentations will be available via CD-ROM for stand alone computers or via a federally funded server on the Internet global computer network.

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A Multimedia-Augmented Software Tutorial for the High Acceptance Recoil Polarimeter Device--Planning Systems, Inc., 7923 Jones Branch Drive, McLean, VA 22102; (703) 734-3450
Dr. E. Scott Baudhuin, Principal Investigator
Mr. Alan J. Friedman, Business Official
DOE Grant No. DE-FG05-94ER81831
Amount: $75,000

This project will assess the feasibility of using multimedia-augmented software tutorials to support teaching the principles of experimental nuclear physics. The detector system for the photon tagging facility at the Continuous Electron Beam Accelerator Facility (CEBAF) in Newport News, Virginia is now under construction at the Nuclear Detector Laboratory of the Center for Nuclear Studies of the George Washington University. The complete tagging system will be used to demonstrate the principles of particle detection used in nuclear and high energy physics, and will relate these principles to a number of illustrative applications anticipated at CEBAF. Phase I will focus on defining the appropriate interactive multimedia-based technologies supporting state-of-the-art educational delivery systems. The feasibility of using full-motion and still frame digital video, digital audio, animation, high resolution graphics, and graphics overlays will be examined. Analyses will also be conducted of different hardware configurations that would be used to support the delivery of the multimedia-augmented software tutorials. The analysis of delivery systems will concentrate on personal computers, CD ROM devices, and digital video solutions. Using the instructional systems development model, the project will design the tutorial, and implement the multimedia instructional design on the selected hardware for a limited set of instructional objectives as a proof of concept. The development of the multimedia-augmented software tutorial proof of concept will be accomplished with selected multimedia authoring systems and tools.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase I results should provide a proof of concept of using multimedia-augmented software tutorials to teach principles in nuclear physics. Phase II should produce a full set of software tutorials on this subject to augment senior undergraduate and early graduate level courses. These tutorials can be offered to universities via CD-ROM. Commercialization could occur via private labels or government sponsorship.

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Innovative Software for Nuclear Physics Education--Scientific Digital Visions, Inc., 954 Emory Street, San Jose, CA 95126-1853; (408) 971-4077
Ms. Jennifer A. Blanc, Principal Investigator
Dr. Craig A. Stone, Business Official
DOE Grant No. DE-FG03-94ER81858
Amount: $74,756

Developing innovative educational software for nuclear physics will provide effective tools for advancing nuclear physics. Topics covered in nuclear courses are intriguing but often difficult to explore. Relational properties of nuclei, theoretical models, and laboratory experiments are cumbersome to apply in these settings. Textbooks provide only a limited and static view of nuclear physics. Students are limited because they cannot easily explore those experiments and facilities they will use through much of their career. Educational tools can more effectively introduce students to concepts, allow them to more thoroughly explore those topics, and facilitate the students' development in the field of nuclear physics. This Phase I project seeks to develop creative and innovative multimedia software for nuclear physics education. Key concepts in nuclear physics can be studied using highly-interactive tutorials that integrate text, sound, animation, and computer-based videos. Some will be electronic laboratories using real or simulated data. Examples include statistics, radioactive decay, and beginning through advanced counting techniques. Electronic laboratories on nuclear models introduce the concepts of the models, along with their applications and limitations. Tutorials and laboratories are supplemented with computer-based movies using videos available through DOE laboratories, time-dependent movies created within the software, and other videos generated through the course of this project. The format may include electronically touring detectors and facilities, viewing results of experiments, or even listening to a noted scientist talk about a significant research result. Electronic bibliographies, time lines of results, and even electronic reprints of major research papers introduce students to the evolution of nuclear physics research. All tutorials and laboratories are accessible through an interactive electronic encyclopedia with an associated dictionary. Special features allow students and instructors to define pathways through the tutorials and information, and permit students to find specific references. The nuclear physics software provides instructors with educational tools for classroom use, for use in electronic nuclear physics laboratories; it is an invaluable resource for developing nuclear physicist.

Anticipated Results/Potential Commercial Applications as described by the awardee: The nuclear physics educational software developed through this project will have significant commercial value. General physics courses often give a superficial coverage to concepts in nuclear physics, because of limited expertise at many universities, and because of the difficulty in supplementing lectures with a laboratory experience. Tutorials and electronic laboratories provide those institutions with practical methods of introducing concepts of nuclear physics. The planned educational software enhances institutions with nuclear physics courses by providing innovative methods of presenting and learning key concepts.

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A Multimedia Tutorial for Charged-Particle Beam Dynamics--Whistlesoft, Inc., 168 Dos Brazos,
Los Alamos, NM 87544; (505) 662-7309
Dr. Richard K. Cooper, Principal Investigator
Dr. Richard R. Silbar, Business Official
DOE Grant No. DE-FG05-94ER81900
Amount: $74,913

The objective of this project is to develop an interactive multimedia course in the physics of charged-particle beams. The level of presentation can be tailored interactively to the knowledge and ability level of the individual pupil, much as the skill level of a video game can be chosen. The student will interact strongly with the teaching program, at his or her own pace. The target market includes high school science students (e.g. advanced placement physics students), college science students, graduate students, and non-expert scientists and engineers interested in the details of accelerators and charged-particle beams. In Phase I, in addition to developing several sample learning modules, the feasibility of linking together all the elements of the multimedia tutorial will be explored. The best way of branching between different skill levels of exposition and making effective transitions between textual displays, graphical displays, and videos, possibly with accompanying sound will have to be determined. The innovative aspect of the development is to learn how to integrate a number of interactive, multimedia tools for the efficient teaching of charged-particle dynamics. The eventual product resulting from this research and development will be a computer tutorial that runs on Microsoft Windows personal computers. The course would be delivered on a CD-ROM disk, together with associated student workbooks and a teacher's manual. The final product would be sold to educational institutions and individuals at a cost small enough ($500 or less) to allow for a large volume of sales. Toward the end of Phase I preliminary meetings with potential publishers of this software will be held.

Anticipated Results/Potential Commercial Applications as described by the awardee: The tutorial to be developed should complement, and perhaps even replace, existing classroom texts. The wider student audience that is targeted would tap a significantly larger market than has previously been addressed. Success in developing these techniques for beam optics could produce many commercial opportunities for developing tutorials in other technical subjects.

TECHNOLOGY AND INSTRUMENTATION FOR HIGH ENERGY ACCELERATORS

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An Inexpensive High-Current Betatron--Adelphi Technology, Inc., 2181 Park Boulevard, Palo Alto, CA 94306; (415) 328-7337
Dr. Melvin A. Piestrup, Principal Investigator
Dr. David G. Boyers, Business Official
DOE Grant No. DE-FG03-94ER81693
Amount: $74,992

The objective of this project is to employ the betatron principle to produce an inexpensive electron accelerator capable of producing 20-50 MeV electrons with good beam quality and high-average currents of up to 5-50 μA. In conventional betatrons which have been in existence for over 50 years, eddy-current losses in the iron limit the operating frequency, thus limiting the maximum energy and current. The use of high-frequency magnetic materials is planned so that driving frequencies of up to a few kHz may be possible, thereby permitting substantially higher average currents. As proof of principle, under Phase I an inexpensive (<$0.2 million), moderate-energy (25 MeV), high-average-current (8 μA) betatron will be designed. The following is also planned: determination of the orbit dynamics at high repetition frequencies; determination of the pole shapes, pole gap, orbit radius, and electron-beam emittance; design of the injection system utilizing orbit contraction/expansion coils and determination of an optimum gun size; design of the extraction system with orbit contraction/expansion coils and a magnetic shunt; and determination of the power supply reactive power and dissipative power requirements. A detailed cost estimate will be prepared with information from vendors to confirm that the cost is moderate and that the high frequency betatron can be a competitor to RF linacs in the commercial marketplace.

Anticipated Results/Potential Commercial Applications as described by the awardee: A compact inexpensive electron source for cancer therapy has obvious benefits of making this therapy more accessible and reducing health care costs. Successful use of the betatron principle for other inexpensive accelerators could also provide for the widespread development of bremsstrahlung, transition, parametric, and channeling radiators. Thus a variety of high-intensity, monochromatic and quasi-monochromatic sources would become available for industrial, medical and military uses.

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A High-Yield and Low-Emittance Positron Source from Coherent Laser-Electron Collisions--Duly Research, Inc., 1912 MacArthur Street, Rancho Palos Verdes, CA 90732; (310) 548-7123
Dr. David U. L. Yu, Principal Investigator
Dr. David U. L. Yu, Business Official
DOE Grant No. DE-FG03-94ER81740
Amount: $74,953

A novel high-yield positron source based on coherent pair creation from the collision of a high power laser beam with a high energy electron beam is planned for this project. The laser-produced positrons have a low transverse emittance and a narrow spectrum, peaking at an energy much below the primary electron beam energy. Spin dependent transverse forces on the created pair provide a natural polarization separation, which can be utilized to produce polarized positrons. The source does not use a solid target, thus avoiding problems associated with the conventional Bethe-Heitler pair creation process. Phase I will develop analytic and numerical tools to simulate the behavior of this promising positron source. These tools will incorporate fundamental physical processes such as spin dependent and quantum effects, the effect of the laser on the motion of primary beam and pair produced particles, shower evolution in the laser background, and spatial and temporal variation of the laser fields. Phase I also includes a study of laser optics and mirror design to maximize collision rate. Research results will be used to establish the feasibility of the new positron source, and will be invaluable in the design of a positron extractor in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned high-yield, low-emittance positron source will reduce the systems cost and complexity in achieving the high luminosity required in future linear colliders. It can also produce copious polarized positrons useful for high energy physics experiments.

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An Electron-Beam "Gatling Gun" for Frequency Multiplying in Microwave Generators--FM Technologies, Inc., 10529-B Braddock Road, Fairfax, VA 22032; (703) 425-5111
Dr. Frederick M. Mako, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG05-94ER81766
Amount: $74,978

A high current, micro-pulse electron source is planned for microwave frequency multiplying. The device utilizes a rotating transverse magnetic (TM_{110}) cavity mode to generate a series of azimuthally distributed bunched electron pulses and is therefore similar to a "Gatling gun". Each azimuthal electron beam pulses time by T/n where T is the radio frequency (rf) period of the rotating mode and n is the number of azimuthal beam pulses created. The bunch pulse length is small compared to the separation time T/n. These electron pulses are transmitted through one wall of the cavity (e.g., by a screen), post-accelerated, and focused electrically and magnetically into an output cavity tuned to an integer multiple of the frequency of the input cavity. As an example, four azimuthal electron pulses from an input cavity driven at 2.5 GHz operating in the TM_{110} rotating mode were considered. The output cavity was selected and confirmed to be resonant at 10 GHz for the transverse magnetic (TM_{040}) mode. The concept of producing one high-current-density azimuthal electron bunch has been studied extensively. In a detailed study of this process, including space charge and emittance, the parameters necessary to make use of the phenomenon to produce a micro-pulsed electron beam were determined. It was shown from self-consistent analytic theory and 2-D particle-in-cell simulations that the current density scales with frequency cubed. This device appears to be capable of high currents ($\gg$kA) and short pulses (psec). Applications for this device are primarily rf generation in the 10 to 20 GHz region, and, in particular, for the next generation of linear colliders. An rf source point design was performed utilizing the Gatling micro-pulse gun. It appears that an output rf power of 100 MW at 11.4 GHz with 61 percent system efficiency is achievable. Phase I is aimed at a detailed analysis to establish credible estimates of power, efficiency, gain, and other key parameters.

Anticipated Results/Potential Commercial Applications as described by the awardee: If successful, this "Gatling" high current, micro-pulse electron gun should provide a high peak power, multi-kiloampere, picosecond-long electron source which is suitable for high power, high frequency rf generators. Of particular interest are 10 to 20 GHz rf generators for the next linear colliders or super-power nanosecond radar

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A Radio Frequency Chopped, Low Emittance High Voltage Electron Source for a 30 MeV, Picosecond Bunch, High Gradient 17 Gigahertz Accelerator--Haimson Research Corporation, 3350 Scott Boulevard, Building 60, Santa Clara, CA 95054-3122; (408) 988-6007
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-94ER81774
Amount: $74,992

This project addresses the design and development of a high resolution low emittance 30 Mev electron source for advanced accelerator research applications, and also supports 17 GHz linear collider research. Phase I investigates the feasibility of designing a demountable type 550 kV electron gun and combining it with a 17 GHz chopping and bunching system to provide a source of low emittance, fully gated radio frequency (RF) bunches of 10^8 to 10^9

electrons, having narrow momentum spread and <20° phase width at entry to a 17 GHz high gradient accelerator structure. Detailed beam optics analyses shall be performed with the objective of optimizing the system parameters to match the injection requirements of an exiting design 17 GHz accelerator structure, ensuring correct capture, bunch compression, and asymptotic bunch location to provide high resolution picosecond bunch (<2°) operation over a wide range of energies up to 30 MeV. Preliminary studies of this high voltage (HV) injector concept indicate that stable injected beams, having small transverse and longitudinal phase space, can be achieved with a higher order mode spatial modulation and charge compression technique using relatively low intensity RF magnetic and electric fields requiring a total peak RF input power of only 3 or 4 kw. A further objective of Phase I is to prepare a test facility layout drawing showing a method of interfacing the proposed HV injection system with an existing high power transmitter, and a prototype 17 GHz high gradient structure, at the Massachusetts Institute of Technology Plasma Fusion Center. In Phase II, the HV injector centerline system shall be fabricated and installed in an existing radiation shielded facility, and the injection system shall be tested with the high gradient structure to investigate the characteristics of the accelerated beam and evaluate the potential of this unique 17 GHz system as a 15 to 30 MeV electron source for advanced accelerator research.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that the Phase I and II efforts will result in the design and fabrication of an RF chopped HV injection system and the high power beam testing of this system with a prototype 17 GHz, 30 MeV electron source suitable for linear collider accelerator research, for advanced accelerator research and development and free electron laser applications, and for investigation of high peak power RF generation at sub-millimeter wavelengths.

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An Efficient Higher Order Multi-Mode High Power Microwave Amplifier--Haimson Research Corporation, 3350 Scott Boulevard, Building 60, Santa Clara, CA 95054-3122; (408) 988-6007
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-94ER81775
Amount: $75,000

Recently published results of the six-year ongoing development of high peak power relativistic klystrons for 11.4 and 14 GHz linear colliders show that none of the tubes have demonstrated efficiencies of greater than 45%, and the majority have operated at less than 35%. In recognition of the potential limitation of these velocity modulation tubes, and because of the beneficial impact a much higher efficiency radio frequency (RF) source would have on linear collider technology, there is considerable incentive to explore new approaches for the high efficiency transfer of power from an electron beam to a coherent flux of accessible high frequency electromagnetic energy. This Phase I effort investigates a new approach for generating microwave power using spatial modulation of a high power electron beam and a novel higher order mode output cavity. The effort is directed at avoiding some of the limitations and difficulties associated with magnicons and higher harmonic (fast wave) devices by attempting to desensitize the dependence of tube efficiency on beam cross section, by operating at moderate values of transverse momentum, by aggressive suppression of multipactor, and by using a relatively large, higher order multi-mode output circuit to minimize dissipation and electric field intensities. The technique is dependent on establishing sets of higher order mode field patterns that coexist within a common boundary yet exhibit extremely high isolation (e.g., 50 to 60 dB) between contiguous and/or orthogonal modes. A further objective of the Phase I effort is to establish specific design parameters for a prototype tube, based on a suitable existing high power test facility (having an RF drive source in the range of 3 to 11.4 GHz), so that in Phase II an economical means will be available for testing the new concept.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that, if successful, the Phase I and II efforts will result in the design and prototype fabrication of a new high efficiency microwave tube suitable for linear collider research and commercial applications that would benefit from a high efficiency source of RF power.

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A Novel Approach to Fabrication of Niobium-Tin Conductor with Artificial Pinning Centers--IGC Advanced Superconductors, 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Leszek R. Motowidlo, Principal Investigator
Mr. B. A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81784
Amount: $75,000

The significance of engineered artificial pinning centers (APC) in niobium-titanium (NbTi) superconductors has been recognized world wide and today is one the most important areas of materials research in applied superconductivity. So far this approach has yielded record high critical currents (J_c) below 4 Tesla (T) field range and at some select fields almost a factor of two better, surpassing that of the conventionally optimized NbTi wires. The importance of the existence of a high performance and economical niobium-titanium (Nb_3Sn) conductor in the United States is the main justification for this Phase I effort. The Phase I work will determine whether the engineering of artificial pinning centers into Nb_3Sn wire will have significant impact on the critical current density. In addition to possible cost reduction through increased conductor performance, this Phase I project will introduce a novel design approach which will have further impact on cost reduction by eliminating the need for a diffusion barrier and therefore eliminating a separate stabilizer billet typical of today's internal tin process.

Anticipated Results/Potential Commercial Applications as described by the awardee: Significant improvement is expected in critical current density at 4.2 K at select fields, and in demonstration of the ability to achieve this increase at any field in the range 8 to 15 T. The combination of an engineered artificial pinning center Nb_3Sn conductor with a new approach for fabrication may result in a very competitive conductor for high field magnet designers in nuclear magnetic resonance devices, accelerator magnets, and the International Thermonuclear Experimental Reactor (ITER).

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Improvement in the Characteristics of Ternary Niobium Titanium Tantalum Alloys--IGC Advanced Superconductors, 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. B. A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81785
Amount: $75,000

In recent years several investigations have been carried out on niobium titanium tantalum (NbTiTa) ternary alloys, and the critical current (J_c) results have not been sufficiently superior to the binary alloy at either 4.2 K or 1.8 K to warrant large scale development. Recent work, however, has shown the reasons for this. The alloys chosen did not have the highest upper critical fields (H_{c2}s) and critical temperatures (T_cs) and the heat treatments used did not appear to be ideal for maximum pinning. The Phase I project will carry out three parallel investigations: (1) A modified heat treatment schedule will be applied to the multifilamentary 25 wt. % Ta, 44 wt. % Ti alloy to improve the size and distribution of the precipitate. This should improve the J_c properties in the medium field range, (2) An alloy already selected on the basis of higher H_{c2} and T_c at 4.2 K will be processed into small billets of a multifilamentary material and its properties compared with the two alloys already fabricated in a similar manner, and (3) An alloy which shows maximum H_{c2} at 2 K and a reasonably high T_c will also be purchased and processed into monofilamentary material and the T_c and H_{c2} determined in this form. In Phase II one or two alloys which show promise will be made into full sized multifilamentary billets and their properties determined.

Anticipated Results/Potential Commercial Applications as described by the awardee: This work should result in the development of an improved material for dipole and quadrupole magnets particularly those which are expected to be used in relatively high field applications. Examples of these are low beta quadrupoles and high field dipoles for sharp bending of the beam, such as is required to direct the beam inside the accelerator ring. In many of these applications high radiation levels are encountered. The niobium tin type materials suffer degradation under these conditions whereas the ternary NbTi-based materials are relatively unaffected.

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Niobium Titanium Multifilamentary Materials with Silicon in the Matrix--IGC Advanced Superconductors, 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. B. A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81781
Amount: $75,000

The aim of this work is to explore further the properties of niobium titanium (NbTi) strands with matrices containing silicon (Si) for high energy physics applications. There are indications that the addition of Si to the matrix will help eliminate the Nb barrier, improve the critical current (J_c), lower the losses, and simplify the process, thus lowering the costs. This improvement is applicable to coarse and fine filament materials. Because of the very promising results and their potentially broad applications, the work will be continued. The previous work with Cu-2.5 wt. % Si and Cu-3.5 wt. % Si matrices confirmed earlier Japanese work and showed J_c's in fine wire material which were 13% higher than those from material with an 8% barrier. It did, however, leave many unanswered questions which will be addressed in this project. Phase I will (1) obtain a better understanding of the chemical and mechanical nature of the material that is formed at the interface between the Si containing matrix and the NbTi filaments, (2) determine more about the dependence of the material's properties on the thermomechanical conditions involved in its formation and how these properties affect the drawability of the composite itself, (3) determine information on the extent to which annealling will be required in the fabrication of the composites containing Cu-2.5 wt. % Si and Cu-3.5 wt. % Si matrices, (4) ascertain if filament uniformity improves, and to what extent this results in improved J_c, and (5) obtain information on how to improve the ductility of a matrix containing both Si and manganese. In Phase II, one or two alloys which show promise will be made into full sized multifilamentary billets and their properties determined.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will ultimately result in lower cost materials with higher J_c's and lower losses in different filament sizes. The work will not only produce optimized material for applications where relatively large filaments can be tolerated (low beta quadrupoles, etc.) but also high J_c material for fine filament applications. This investigation will lead to materials which will have broad uses in high energy physics and very wide applications throughout the many fields where superconductors are used.

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Development of a Radio Frequency Quadrupole-Focused Drift Tube Linac Structure--Linac Systems, 115 Morene Avenue, Waxahachie, TX 75165; (214) 937-3283
Dr. Donald A. Swenson, Principal Investigator
Mrs. Barbara C. Swenson, Business Official
DOE Grant No. DE-FG03-94ER81797
Amount: $74,976

A new linear accelerator (linac) structure will be identified and investigated in Phase I as a possible extension to the family of structures now used for acceleration of charged particle beams. A candidate structure has been identified; others may be identified in the course of the investigation. The identified structure utilizes a four-fingered geometry to produce radio frequency (rf) electric quadrupole fields to focus the beam. It resembles a drift tube linac (DTL) structure with radio frequency quadrupole (RFQ) focusing, thereby opening the possibility of higher frequency and high gradient operation. Included in the investigations of the RFQ-DTL structure will be detailed analysis of the rf fields surrounding the four-finger electrodes and the effect of those fields on the particle beams passing through them. Issues such as the rf efficiency of the structure, the stability of the fields with the structure, methods of fabrication, and methods of excitation will be addressed. Models of some critical components and/or assemblies will be fabricated for evaluation. The role of this new structure and its impact on accelerator technology will be identified.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is expected that the new rf-focused linac structure, identified in Phase I and developed in Phase II of this project, will open the door to higher frequency, smaller, and more economical sources of accelerated particles and applied radiation for a whole host of applications. Linac systems, based on these new structures in conjunction with RFQ and DTL linacs, should represent viable commercial products.

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Optimization of Beam Shaking Techniques for the Removal of Trapped Ions in Antiproton Storage Rings--Lodestar Research Corporation, 2400 Central Avenue, P-5, Boulder, CO 80301; (303) 449-9691
Dr. James R. Myra, Principal Investigator
Dr. Richard E. Aamodt, Business Official
DOE Grant No. DE-FG05-94ER81798
Amount: $75,000

Many experiments in the frontiers of high energy physics require high luminosity as well as high energy beams. For proton-antiproton colliders, this requirement leads to the need for antiproton storage rings with smaller emittance, capable of operation at high current, and with the avoidance of catastrophic beam loss. Experiments at both CERN and Fermilab have shown that trapped ions in the antiproton accumulator (AA) are associated with limitation on these operational parameters. In this investigation, theoretical studies leading to improved methods of trapped ion removal are considered. The work will be done in collaboration with ongoing experimental work at Fermilab. The proposed scheme will optimize existing beam shaking techniques in the collective plasma regime appropriate to highly stacked beams. Phase I will develop a Vlasov theory of trapped ion equilibria, collective modes and the corresponding quasilinear (QL) theory including Landau wave-particle interaction with the trapped ions. The QL theory will yield trapped ion removal rates for the Fermilab AA as a function of collective mode amplitudes excited by beam shaking, and enable the calculation of the associated shaker power requirements. The Phase I effort will set up all necessary tools for complete identification and optimization of strategies for beam shaking. Assessment of possible scenarios (e.g., choice of collective mode, operating point for beam/trapped-ion coupling, and time sequencing of shaker power and frequency modulation) will begin in Phase I and is the major goal of Phase II, which will enable the design of an optimized shaker. Some of the techniques developed will be applicable more generally to other accelerators with negatively charged beams.

Anticipated Results/Potential Commercial Applications as described by the awardee: This work will enable the design (of new equipment, if needed) and the operational scenarios for optimal removal of trapped ions by beam shaking techniques. It will extend previous single particle descriptions of beam shaking and trapped ion removal to the collective plasma regime appropriate to Fermilab AA operation with highly stacked beams. The end result will be a significant new tool for obtaining higher antiproton beam currents, lower beam emittance, and therefore improved performance of the accelerator as a whole.

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Superconducting Magnet Development for Compact Storage Rings--Particle Beam Lasers, Inc., 18925 Dearborn Street, Northridge, CA 91324; (818) 885-8956
Mr. Alper Garren, Principal Investigator
Mr. James J. Kolonko, Business Official
DOE Grant No. DE-FG03-94ER81826
Amount: $75,000

This project will study and develop a type of high field superconducting magnet for positron-electron colliders, damping rings for the next linear collider, and a compact synchrotron light source with X-ray energies between 15 and 33 keV. The Phase I study will identify a superconducting magnet configuration that will satisfy the requirements of a dipole magnet of a compact storage ring based on the Vobly design and test the suitability of this magnet in a specific storage ring example. The configuration will consist of the geometry of the iron poles, the shape and locations of the coils, the required relationships of the currents in the independent coils, and the magnetic multipole functions as a function of position and currents. In addition to magnet design studies, the effort will also consider other aspects of the storage ring including the lattice, quadrupoles, vacuum, radio frequency, and injection systems. A preliminary estimate of the magnet cost and storage ring cost will be made.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful development of a high field superconducting compact bending magnet will permit one to build small compact storage rings and hard X-ray sources for commercial and medical applications. The research could have spin-off applications in other fields such as protein crystallography, coronary angiography, mammography, and nano-technology.

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High Quality Chemically Vapor Deposited Niobium Coatings for Superconducting Radio Frequency Cavities--Sumi Tech, Inc., 3006 McLean Court, Blacksburg, VA 24060; (703) 552-8334
Mr. Wei Tao, Principal Investigator
Mrs. Mallika D. Ilindra, Business Official
DOE Grant No. DE-FG05-94ER81871
Amount: $75,000

Traditionally, superconducting cavities for large electron position colliders are fabricated from high purity niobium (Nb) sheets using lathe spinning and welding. These cavities suffer from the problem of thermomagnetic breakdown resulting from the relatively poor thermal conductivity of Nb at liquid helium temperatures. A more elegant and low cost solution to the breakdown problem is the use of Nb coated high purity copper (OFHC copper) superconducting cavities. However, the low field Q values of 2×10^9 at 4.2 K dropped rapidly with increasing field; for example at 3 MV/m the $Q = 3 \times 10^8$. The loss in the Q value of Nb-coated copper cavities may be attributable to the columnar grain structure, low packing density, and surface roughness of the Nb coating. In contrast to sputtering, chemical vapor deposition (CVD) will allow deposition of excellent quality films on substrates with complex geometries, such as superconducting cavities, with relative ease. In addition, CVD of Nb will possibly give dense, smooth, and fine grain Nb films, which will definitely have much better properties than those obtained by sputtering. The Phase I objectives are: a) to determine the best precursor for CVD of Nb films on copper substrates, and b) to optimize the CVD deposition conditions for Nb films on copper substrates. The Phase II objective is to build a Nb-coated copper superconducting cavity by CVD.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project provides an alternative solution to the problems encountered in superconducting cavities for large electron positron colliders. In addition to the accelerator application, Nb coatings are widely used for nuclear fuel particles.

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Development of Niobium-Titanium-Tantalum Artificial Pinning Center Superconductors for Very High Field Applications--Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545; (508) 842-0174
Dr. Jeffrey M. Seuntjens, Principal Investigator
Ms. Elaine Drew, Business Official
DOE Grant No. DE-FG02-94ER81874
Amount: $74,954

The best enhancement in critical magnetic field (H_{c2}) for niobium titanium (NbTi) alloys has been found for a 15 to 25 wt. % ternary addition of tantalum. The precise alloy composition for the best combination of critical temperature (T_c), H_{c2}, precipitation kinetics, critical current (J_c) and ductility are still of considerable debate because NbTiTa alloys to date have not significantly outperformed binary NbTi. A process has been developed for the manufacture of NbTi composite superconductors using an artificial pinning center (APC) approach. The APC process has been extended to NbTiTa material, and model conductors show an adequate ductility and similar J_c to binary APC composites. Phase I will work to establish the best raw material configuration as well as the thermal and mechanical processes in model APC NbTiTa superconductor material. The Phase I and the anticipated Phase II efforts will complement and build upon the existing ternary conductor research and could result in a proven commercial process for ternary APC conductor. Ternary APC conductors have greater potential for higher J_c at optimal compositions than ternary approaches using melted alloy.

Anticipated Results/Potential Commercial Applications as described by the awardee: Development of these ternary APC conductors has greater potential for higher J_c at optimal compositions than ternary approaches using melted alloy. Ternary conductors which can incorporate the potentially higher H_{c2} into greater high field (>8 T) J_c than comparable binary alloys will find immediate use in high energy physics applications. This effort builds upon ternary APC experience to establish the best raw material configuration as well as the thermal and mechanical processes for APC NbTiTa superconductors.

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Niobium-Titanide Tin/Copper Multifilamentary Superconducting Wire with Niobium/Titanium Composite Filaments--Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545; (508) 842-0174
Dr. Dingan Yu, Principal Investigator
Ms. Elaine Drew, Business Official
DOE Grant No. DE-FG02-94ER81873
Amount: $74,995

The accelerator, fusion, and nuclear magnetic resonance (NMR) projects in the field of applied superconductivity all require new high-field superconducting wires that have higher current-carrying capability in higher magnetic fields. Up to now, niobium tin (Nb_3Sn) is the most important practical superconductor for high-field applications. One of the effective approaches to raise the critical current densities of Nb_3Sn in high magnetic fields is to alloy Nb_3Sn with titanium (Ti) or tantalum (Ta). The current practice of adding Ti into Nb_3Sn is to use NbTi alloy rods and/or cooper (Cu) bronze matrix alloyed with Ti to assemble the monocore billets. Nevertheless, the processing of these conductors often suffers from drawability problems due to enhanced work hardening. Phase I will investigate the feasibility of developing a ternary $(Nb,Ti)_3Sn/Cu$ multifilamentary superconducting wire with Nb/Ti composite filaments prepared from pure Nb and Ti sheets using a jelly-roll technique. It has been demonstrated that long lengths of NbTi superconductor with artificial pinning centers (APC) can be fabricated from pure Nb and Ti sheets without precipitation heat treatments. It is expected that use of Nb/Ti composite filaments via a jelly roll technique will improve the fabricability of the $(Nb,Ti)_3Sn/Cu$ superconducting wire and cut the cost. The fine grain structure in Nb and Ti sheets will also help to enhance the critical current (J_c) in low and intermediate magnetic fields, and reduce the filament sausaging at the same time. In Phase I, two ternary $(Nb,Ti)_3Sn/Cu$ superconducting wires, one containing Nb/Ti composite filaments and the other containing conventional Nb/1-2wt.%Ti alloy filaments, will be fabricated using a conventional bronze-route process. The drawability, J_c, magnetization (hysteresis loss), and microstructure of these two wires will be measured and compared. The further optimization and scale-up work will be conducted in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will result in a ternary $(Nb,Ti)_3Sn/Cu$ superconducting wire with Nb/Ti composite filaments. This superconducting wire with an enhanced high-field J_c, better drawability, and reduced fabrication cost will be an ideal candidate to be used in the superconducting magnets for accelerator, fusion, and NMR projects.

196

Object Oriented Programming for Accelerator Design and Analysis--Tech-X Corporation, 6175 Habitat Drive, #3076, Boulder, CO 80301; (303) 530-9562
Dr. Svetlana G. Shasharina, Principal Investigator
Dr. John R. Cary, Business Official
DOE Grant No. DE-FG05-94ER81884
Amount: $74,739

This project will investigate and document the use of object oriented programming for analysis and design of accelerators by porting existing codes to C++ and using and enhancing an existing class of accelerator elements in a design code. Specifically, the code maps will be ported to a C++ compiler and the beamline class to the C++ compiler of IBM workstations. Coding for accelerator elements in xmaps will be replaced with beamline classes. These replacements will be tested and verified for accuracy at each stage. Finally, documentation of the accelerator classes and their usage will be provided.

Anticipated Results/Potential Commercial Applications as described by the awardee: Result will be a tested set of accelerator element classes that should be available to national laboratories and the public for accelerator design and analysis. These classes will be documented for ease of use.

197

A Porous Metal Cooled Klystron Collector--
Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601; (717) 569-6551
Mr. John H. Rosenfeld, Principal Investigator
Mr. Richard W. Longsderff, Business Official
DOE Grant No. DE-FG05-94ER81889
Amount: $74,985

The objective of this program is to demonstrate the capability of porous metal cooling to effectively remove heat absorbed by a multi-stage depressed collector of high power B-factory klystrons. Heat to be removed can typically be many kilowatts, and peak heat fluxes can exceed 1000 W/cm^2. Existing channel cooling designs are generally limited to heat fluxes of less than 1000 W/cm^2. Porous metal cooling will increase the power capability and design margin for the klystron collector. Tasks to be completed in Phase I include defining detailed requirements for the collector, completing a conceptual design of a porous metal cooled heat exchanger for the target application, and demonstration of a subscale test article to remove an absorbed heat flux goal of 1000 W/cm^2 to 2000 W/cm^2 using porous metal cooling.

Anticipated Results/Potential Commercial Applications as described by the awardee: Reliable operation of klystrons with collector heat fluxes of over 1000 W/cm^2 could be possible for the first time. Applications may also exist for cooling of solid-state electronics, fusion energy components, and aerospace components.

HIGH ENERGY PHYSICS DATA PROCESSING AND DETECTOR INSTRUMENTATION

198

Ultraviolet-Sensitive Large-Area Avalanche Photodiodes for Improved Calorimetry--
Advanced Photonix, Inc., 1240 Avenida Acaso, Camarillo, CA 93012; (805) 987-0146
Mr. John Montroy, Principal Investigator
Mr. S. C. Han, Business Official
DOE Grant No. DE-FG03-94ER81697
Amount: $74,895

This project will extend the responsivity of currently available large-area avalanche photodiodes (APDs) into the blue and near-UV region. APDs can offer significant cost savings and superior performance (high quantum efficiency, compactness, ruggedness, freedom from afterpulsing, magnetic field immunity, and fast time response) over photomultipliers. During Phase I, two parallel approaches will be explored to enhance APDs' blue and near-UV responsivity using boron implantation and wavelength-shifting phosphor coating. The goal is to achieve a 40% quantum efficiency in the wavelength region 200-450 nm. A successful completion of Phase I will demonstrate the feasibility of the technical approach. Phase II would optimize these processes and develop prototype APDs and APD arrays that are sensitive in the blue and near-UV region.

Anticipated Results/Potential Commercial Applications as described by the awardee: Large-area APDs with enhanced blue and near-UV responsivity will have applications for readout of Aerogel Cerenkov counters and blue scintillating fibers, as well as time-of-flight detectors at the Fermi Lab. Other commercial applications include chemical analysis instruments such as mass spectrometers and activation analysis systems.

199

The Peripheral Component Interconnection/ Scalable Coherent Interface Bridge for Data Acquisition and Computation Applications--Bi Ra Systems, Inc., 2404 Comanche Road, NE, Albuquerque, NM 87107; (505) 881-8887
Mr. Lavon R. Biswell, Principal Investigator
Mr. Lavon R. Biswell, Business Official
DOE Grant No. DE-FG05-94ER81716
Amount: $75,000

Coalescing the fragmented information associated with each event of a high-energy physics detector and then processing it at the rates demanded by accelerator systems are among the largest challenges in the physics community. New detector systems continue to increase the number of measured parameters and simultaneously increase the resolution of detector components so that the volume of generated information is exploding. Data acquisition and computation systems now face staggering amounts of data to both move and process. A peripheral component interconnection (PCI)/ scalable coherent interface (SCI) bridge (PSB) that solves both of these data acquisition and computation issues will be developed. This bridge links the high performance PCI, the emerging standard for the internal bus of desktop computers, to the recently developed SCI IEEE standard 1596-1992. Scalable farms (groups) of inexpensive PCI-equipped desktop computers will connect to large detector systems through the PSB and the highly configurable SCI network to satisfy data rates and to process events from thousands of distributed subsystems. The Phase I research will develop a specification for the PCI/SCI bridge following the form of the proposed 1596.1 SCI VME bridge standard. This work will ensure compliance with both the PCI Local Bus Specification Revision 2.0 and IEEE Standard 1596-1992. A preliminary design minimizing cost through use of commercial components will be developed, PCI/SCI transactions simulated, and bridge latency and throughput performance estimated.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that the high performance and versatile architecture of the PCI/SCI bridge will make it an essential building block in the data acquisition and computation systems for high-energy physics experiments now in the planning stages for upgrades or for new construction in the United States and elsewhere. Because of its low latency and high bandwidth, this bridge will be a component of low cost supercomputing clusters in a broad scientific and business market. Such cluster computing accelerates execution of software programs except those that make significant use of vector processing.

NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

200

A High Power, Thick Target Design for Irradiation by High Intensity Charged Particle Beams--Amparo Corporation, P.O. Box 2687, Santa Fe, NM 87504; (505) 982-6742
Dr. Willard L. Talbert, Principal Investigator
Dr. James J. Walker, Business Official
DOE Grant No. DE-FG05-94ER81704
Amount: $74,377

Phase I addresses a new approach for the design of high power nuclear targets used for production of radioisotopes by high energy charged particle beams, notably high energy protons. Such targets will yield larger quantities of radioactive species than presently available, either for basic research (e.g., studies using radioactive beams) or for applied purposes (e.g., production of medical radioisotopes). There is a need, especially for the production of short-lived radioisotopes, to develop nuclear targets that optimize production of isotopes in the vapor state. This allows on line collection and processing, thus greatly improving the net production efficiency for a given high energy particle beam. This improvement will be achieved by the ability to set the target operating temperature to optimize the diffusion and desorption of the radioisotope species of interest. To this effect, the feasibility of a new target design, utilizing thermal impedance materials such as porous metals and woven wire meshes interposed between the target chamber proper and the cooling jacket will be studied. Such an approach has attractive features for controlling the transport of heat, and has been proposed in initial concepts for a radioactive beam facility at TRIUMF (Vancouver, B.C., Canada). Successful completion of Phase I will lead to the production of a target prototype to be tested at an existing accelerator facility.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated results of this project are to provide a design basis for target development, to be used in follow-on tests at a high current accelerator, and to provide design options that allow target designs to be developed for a wide range of target operating temperatures. Potential commercial applications include the production of short-lived medical radioisotopes and the potential for on line conventional medical isotope production and separation.

201

Jet Vapor Deposition of Thick Films for the Production of Radioactive Beams of Chemically Active Elements--Jet Process Corporation, 25 Science Park, New Haven, CT 06511; (203) 786-5130
Dr. Bret L. Halpern, Principal Investigator
Mr. Jerome J. Schmitt, Business Official
DOE Grant No. DE-FG05-94ER81793
Amount: $75,000

Radioactive nuclear beams (RNBs) are powerful tools for research in nuclear physics and astrophysics, and for applications in medicine and materials science. In the United States a large laboratory for intense RNBs is contemplated, and smaller facilities exist in several countries; worldwide interest in RNBs reflects their potential importance. RNBs are generated when high energy proton beams interact with specialized, expensive, isotopically enriched targets and release short-lived radioactive species. A critical requirement is that products escape the target promptly lest radioactive decay diminish beam intensity. Target design is complicated by the demands of high yield, efficient use of isotopic materials, chemically reactive products, and prompt release. Targets for production of radioactive ^{14,15}O and ^{17,18}F are considered of highest priority, but have not been made. Phase I will solve this problem by using a proprietary jet vapor deposition (JVD) method to deposit multilayer and porous nanocluster thin film RNB targets. Success in Phase I will provide a unique JVD approach to RNB target fabrication and two new types of RNB target. Phases II and III will lead to JVD scale up for commercialization of RNB targets and nanostructure spinoff products.

Anticipated Results/Potential Commercial Applications as described by the awardee: Success in Phase I would prove a new method for making RNB targets of reactive elements. These are expensive, hard to fabricate components critically needed at future RNB facilities both for fundamental research and for applications in materials science and medicine. The JVD techniques developed will also lead to spinoffs in nanostructured thin film products.

202

Radiation Detectors Based on Room Temperature Silicon Drift Chamber Arrays--Moxtek, Inc., 452 West 1260 North, Orem, UT 84057; (801) 225-0930
Dr. Mark W. Lund, Principal Investigator
Mr. Lester Y. Moody, Business Official
DOE Grant No. DE-FG05-94ER81817
Amount: $75,000

Several detector technologies have been developed recently in American and European government and university research laboratories. These technologies combined with planned innovations could be used to create a new type of silicon x-ray detector-spectrometer that has resolution and sensitivity close to present lithium drifted silicon (Si(Li)) detectors, but operates at room temperature. The technologies include silicon drift chambers and Junction Field Effect Transistors (FET) on high resistivity silicon. Combining these innovations on high resistivity epitaxial silicon could produce a room temperature detector which will be competitive with currently available energy dispersive x-ray detectors without the high cost and maintenance associated with liquid nitrogen cooled Si(Li) detectors. They could also have much more collection area than a PIN photodiode of the same resolution. Phase I will develop the low capitance FET and reset mechanisms necessary for high resolution drift chambers, and design the semiconductor process and the first draft of the drift chamber layout.

Anticipated Results/Potential Commercial Applications as described by the awardee: Chemical elemental analysis by x-ray fluorescence is a well established technique, but one which requires laboratory based cryogenic equipment. The planned product would open up many more applications for this technique, including mobile, hand held, airborne, and space borne applications. This is a technology that should be useful in current applications which use Si(Li) detectors, and also could open up more applications in space and on earth for these spectrometers. Applications would include prospecting, environmental contamination surveys, scrap metal sorting, process control, and nuclear proliferation monitoring. It is estimated that the market for room temperature detector-based energy dispersive is larger than that for cryogenic detectors.

203

A Feasibility Study of a P-Type Silicon Drift Detector for High Precision Radiation Measurements--NOVA R & D, Inc., 1525 Third Street, Suite A201, Riverside, CA 92507-3429; (909) 781-7332
Dr. Charles J. Naudet, Principal Investigator
Ms. Sezen H. Tumer, Business Official
DOE Grant No. DE-FG03-94ER81820
Amount: $75,000

Nuclear physics experiments need high energy resolution position sensitive particle detectors. The planned experiments at the Relativistic Heavy Ion Collider also require tracking charged particles in a very high multiplicity environment. New state-of-the-art position sensitive detectors are needed. This Phase I project will study the feasibility of a high precision, low cost, position sensitive charged particle tracker, a p-type silicon drift detector (SDD). Prototype versions of n-type silicon drift detectors have been successfully implemented in heavy-ion and high energy physics experiments where they have demonstrated high spatial precision and durability. However, because of the difficulty of obtaining quality high resistivity n-type silicon these detectors have not yet been widely used. High resistivity p-type silicon is readily available and also offers advantages. This Phase I project will focus of the development of large area (>16 cm^2) p-type silicon drift detectors. Experiments and simulations will be conducted to study the position and energy resolution, radiation resistance, temperature gradient effects, and optimization of the integrated calibration system. Phase II will extend the development of large p-type SDD to include the production and testing of charged particle tracking and x-ray SDDs, and the devices will be developed for the manufacture of commercial detectors for industrial and scientific applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: A low cost, large area, radiation resistant, precise SDD would find a demanding market not only for charged particle tracking in nuclear physics experiments but also in heavy ion, high energy, and plasma physics. It can be also used in x-ray and gamma ray astronomy. The development of similar x-ray SDDs will find potential uses in commercial applications such as x-ray fluorescence, medical and industrial x-ray imaging, Mossbauer spectrometers, nuclear waste monitoring, and commercial x-ray and gamma ray detectors.

204

A Wide Tunable Ultraviolet Detector for a Cherenkov Particle Detection System Using Gallium-Nitride/Aluminum-Gallium-Nitride Multiple Quantum Well Structures--Physical Optics Corporation, 2545 West 237th Street, Suite B, Torrance, CA 90505; (310) 320-3088
Dr. Sueh-Wen Siao, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-94ER81827
Amount: $74,994

The weak ultraviolet (UV) light generated by charged particles traversing an appropriate medium in a ring-imaging Cerenkov (RICH) detection system requires a very sensitive detector array to give the spatial location and the velocity vector of the particles. The low sensitivity of commercially available UV detectors requires the implementation of an external image intensifier, which is bulky, expensive, and fragile. It is planned to fabricate a UV avalanche detector array for identifying the charged particles in RICH detectors. The novelty of this UV detector is the avalanche effect via impact ionization of electrons and holes in a gallium nitride/aluminum gallium nitride multiquantum well (MQW) structure. The MQW is designed to provide high efficiency and high speed operation by controlling the impact ionization rate of electrons and holes separately. The avalanche effect provides an internal gain that increases the sensitivity of the detector by at least five orders of magnitude. This will eliminate the use of the external image intensifier needed for conventional detection systems. This UV detector has high sensitivity and a large bandwidth. In addition, it is efficient, highly reliable and cost effective for the RICH system. In Phase I a prototype device will be fabricated to demonstrate the feasibility of this concept. In Phase II a fully functional detector array will be fabricated using the optimized parameters.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful development of the UV detector will result in an efficient, rugged, highly sensitive, and low cost device to be used in RICH particle identification systems. Other applications of the device include laser power measurements, calorimeters, medical analytical instrumentation, industrial processing equipment, pollution monitoring instrumentation, spectroradiometers, and densitometers.

205

A Novel Solid State Ultraviolet Detector for Scintillation Readout--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Dr. Chuxin C. Zhou, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-94ER81843
Amount: $75,000

The overall performance and usefulness of scintillator detectors are often limited by the efficiency of light collection by the photosensor used in conjunction with them. Most scintillators that emit in the ultraviolet region (UV) have not been fully exploited, chiefly due to the difficulty of measuring the light output in that range. For example, BaF_2 is an attractive scintillation detector for γ-rays, neutrons and charged particles because of its radiation hardness and fast time response. However, since its fast light component is well into the UV, only Photomultipliers Tubes (PMTs) with special UV transmitting windows can be used. Even the special PMTs do not achieve good performance with these scintillators, and they are expensive. The plan is to develop a novel solid state photosensor which will have the exceptional performance, in the ultraviolet region of the spectrum, that will take full advantage of the performance of these UV scintillators. This sensor can be fabricated in the form of high resistivity, low deilectric constant films, has excellent radiation hardness and has a tunable bandgap which optimally covers the UV spectrum of interest. This device will be made using the ternary semiconductor Gallium Aluminum Nitride ($Ga_{1-x}A_x1N$). With this new device, it should be possible to make very compact, rugged and extremely high performance scintillator modules which could find wide applications in nuclear instrumentation technology.

Anticipated Results/Potential Commercial Applications as described by the awardee: $Ga_{1-x}A_x1N$ photodetectors would offer a solid state replacement to PMTs for light detection from scintillators that emit in the UV and are used in intermediate and high energy physics experiments. In general, $Ga_{1-x}A_x1N$ detectors would also find applications in detection of UV radiation from flames in combustion control in industrial processes and for surveillance in space applications. Monitoring of UV processes like UV curing and UV photolithography could also benefit from it.

206

Low Cost Avalanche Photodiodes for Scintillation Detection--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Dr. Gerald Entine, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-94ER81842
Amount: $75,000

Silicon avalanche photodiodes (APDs) have been shown to be nearly an ideal replacement for photomultiplier tubes (PMTs) in scintillation detection applications. However, because of their great expense (typically APDs cost ten times as much as an equivalent PMT) APDs have not been widely used. The high cost of APDs is due to the low yield, labor-intensive manufacturing process used to produce them. The purpose of this project is to develop a new APD design that can be manufactured entirely using automatic methods employed in the integrated circuit (IC) industry. The goal of the Phase I effort is to demonstrate that it is possible to fabricate APDs with performance comparable to present devices using standard silicon IC processing technologies. During Phase I an appropriate APD structure will be designed and the necessary fabrication steps developed and tested. By the end of Phase I, APDs will be fabricated using this process and tested as detectors. Phase II of this effort will continue the research and examine ways to improve performance and reduce cost to produce a process that is compatible with larger scale, low cost silicon device manufacturing. If successful, the proposed research would result in a low cost solid state alternative to PMTs.

Anticipated Results/Potential Commercial Applications as described by the awardee: These devices would find widespread use as a PMT replacements in nuclear physics research for scintillation detector applications, and should have a large commercial market.

207

Microchannel Plates Fabricated by Track Etch Lithography--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Charles C. Blatchley, Principal Investigator
Mr. Patrick N. McDonnell, Business Official
DOE Grant No. DE-FG02-94ER81868
Amount: $74,981

Tiny channels can be formed in polymers and glass by chemical etching along columns of radiation damage created by alpha particle bombardment through microscopic holes in a dense mask. The objective of Phase I research is to determine whether a dense packing of these channels, carried through the irradiated substrate, can reliably form micro channel plates (MCP) suitable for amplifiers for imagers and other optoelectronic devices. The reduction in channel diameters compared to those characteristics of drawn glass-fibers will preserve gain and efficiency while improving spatial resolution and response time. Most significantly, this will greatly reduce costs through a simple two-step process similar to photolithography where holes in a mask are positioned to optimize channel locations. Phase II would use this deep ion-damage etching process to make large plates with identical channel locations, providing high registration efficiency over large areas and further improving the resolution of finished devices.

Anticipated Results/Potential Commercial Applications as described by the awardee: Microchannel plates are used in imaging, ranging, and night vision instruments. Many medical imaging systems, mass spectrometers, scintillation detectors, and optical communication links rely on this technology, and would benefit from the expected improvements in resolution, response, and fabrication cost.

208

Low Cost Substrates for Micro-Strip Gas Chambers--Surmet Corporation, 33 B Street, Burlington, MA 01803; (617) 272-3250
Mr. Richard A. Cooke, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-94ER81876
Amount: $75,000

Micro-Strip Gas Chambers (MSGC) are high resolution counting devices for detecting events produced by particle-particle and heavy ion collisions in high energy accelerators. They are of great interest because of their fine granularity, high, gain and potential for low cost, large area event detection. MSGCs have been demonstrated by several research and industrial concerns and the early results suggest that large area (250 mm x 180 mm) devices can be manufactured that will suit the research needs. Manufacturing of MSGCs follow the methods of the microelectronics industry, with thin film technology and microlithography playing key roles in depositing patterned metal films on insulating substrates. Current estimates for the large scale manufacturing of a single MSGC are about $700 for a 100 mm^2 device, not including the cost of the substrate. Unfortunately, the current estimates for substrate cost are about equal to the device manufacturing cost. Clearly, the development of a low cost substrate is crucial to making this device economically feasible. A low cost multilayered thin film structure is planned to achieve the required properties and to provide a surface with a sheet resistance that is controllable in the 10^{12} to 10^{14} ohms/square range. A low cost flexible engineering polymer will be used as a substrate onto which the multilayered thin film structure will be deposited. Excellent adherence to the metal electrodes to the proposed surface is also expected. Cost for a MSGC substrate using this technique is estimated to be less than 1/10 of the current estimated substrate cost.

Anticipated Results / Potential Commercial Applications as described by the awardee: Micro-Strip Gas Chambers are seen as a critical component of future particle event detection devices for high energy physics research. The development of a low cost substrate for MSGCs should make them economically feasible. The technology to be developed through this program could have application to both the microelectronics field and the expanding fields of large area coating of polymers for electronics, biomaterials and tribological applications.

209

Radiation-Hard and Solar Blind Ultraviolet X-Ray Chemically Vapor Deposited-Diamond Photodiode Detectors--Vactronic Laboratory Equipment, Inc., 160 Wilbur Place, Bohemia, NY 11716; (516) 567-0520
Mr. Glenn Fricano, Principal Investigator
Mr. Robert Salat, Business Official
DOE Grant No. DE-FG02-94ER81896
Amount: $73,902

This project deals with the development of radiation-hard and solar blind photodetectors made from chemical-vapor-deposited (CVD) diamond, tailored to have responsivities between 5 eV and 5 keV, i.e., from ultraviolet (UV) wave lengths down to the X-ray region. Being a wide bandgap semiconducting material, its electrical properties include, among others, (a) solar blindness, meaning that it is not sensitive to visible light, and (b) very low leakage (or dark) current, even under high voltage bias and at elevated temperatures. The first property allows convenient applications under normal daylight and room illuminations. The latter results in low noise figures significantly better than those of silicon photodetectors presently in common use. Two different structures or prototypes of photodiodes will be optimized in Phase I. The first is a conventional metal-semiconductor-metal structure, in which a CVD diamond layer is sandwiched between two metal layers or electrodes. The second type of photodiode is furnished with alternating lines of metal electrodes arranged side-by-side, facing the incoming radiation, such that shallow light penetrations do not impede its performance. By virtue of proper design, this type of photodiode is expected to be capable of very high frequency operations in the 100 GHz range, although the Phase I goal is only 4 GHz. For both prototypes, one-inch diameter intrinsic diamond films on molybdenum substrates will be grown using a microwave plasma reactor and metalized using carbide-forming metals such as titanium and molybdenum along with gold in an electron-beam evaporator.

Anticipated Results / Potential Commercial Applications as described by the awardee: Potential applications of these new photodiodes are (a) as robust, room-temperature, solar blind, position-sensitive UV and X-ray (array) detectors for use in medicine, space astronomy, high altitude atmospheric research, non-destructive material testing (NDMT), nuclear and high energy physics, fusion research, and safeguards/security inspections; (b) as X-ray fluorescence detectors in nuclear waste management, environmental restoration, NDMT, and nuclear non-proliferation; (c) as radiometric transfer standard detectors for use by the private industry, government, and military; and (d) as high-speed receivers for fiberoptic communications.

210

Dynode Material Studies for a Novel Two Dimensional Electron Multiplier--X-Ray Instrumentation Associates, 2513 Charleston Road, Suite 207, Mountain View, CA 94043-1607; (415) 903-9980
Dr. Yuan Kong, Principal Investigator
Dr. William K. Warburton, Business Official
DOE Grant No. DE-FG03-94ER81902
Amount: $75,000

The photomultiplier tube (PMT), consisting of a photocathode and a dynode based electron multiplier (EM), is an important electro-optic device in a variety of radiation measurements. It is a versatile and sensitive detector with low noise and fast response time. The EM dynode structures, however, preclude fine grain, two-dimensional (2-D) position sensitivity using conventional designs. Mesh dynodes have been developed to address this issue but, due to lateral spreading of the electron avalanche between stages, are still typically limited to 1-2 mm in position resolution. This project proposes a novel EM design that should achieve resolutions of 100 µm or less while preserving the benefits of the classical dynode structure. Other benefits include: count rates up to 10^7/sec per $(100\mu m)^2$ pixel, improved timing resolution, essential gain independence of axial magnetic field, and the possibility of active areas up to 20 cm in diameter. Phase I will focus on dynode material identification and selection, which is the key element in the new geometry. Success in this project will provide the necessary basis for developing a 2-D electron multiplying structure that would have a wide range of instrumentation applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: Success in this project will lead to the development of a 2-D imaging electron multiplier structure that will possess several improved characteristics over presently available devices. Count rate capability, 2-D spatial resolution, timing resolution, and magnetic field immunity are all expected to improve greatly. Such a device would enhance performance in applications ranging from nuclear physics to medical and biological imaging, and would open new horizons in a variety of fields.

NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

211

A High Power Solid-State Amplifier--Amparo Corporation, P.O. Box 2687, Santa Fe, NM 87504; (505) 982-6742
Dr. Don W. Reid, Principal Investigator
Dr. James J. Walker, Business Official
DOE Grant No. DE-FG05-94ER81703
Amount: $74,607

During the past 10 years significant progress has been made in the performance characteristics of solid-state devices. The output power capability has substantially increased, the efficiency has almost doubled, the reliability, when operated conservatively, has always been better than tubes because of graceful degradation characteristic, and the cost per device has decreased. These and other positive solid-state amplifier characteristics will be applied to the design of a state-of-the-art 5 Kw, 1500 Mhz, 40% efficient, 45 dB amplifier that could replace the present Continuous Electron Beam Accelerator Facility (CEBAF) klystron tube. The use of an integral dc to dc converter will be investigated. The converter would be part of the amplifier package and would enable the amplifier to run directly from the 11.6 kV dc voltage bus that presently exists. The end result would be an amplifier with better efficiency, more gain, better reliability, easier maintenance and lower system operating cost than the existing tube. In addition, the amplifier could replace the existing tube with only minor system modifications.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful development of this amplifier should be directly beneficial to CEBAF where it can potentially replace 338 klystrons. There could also be a large potential commercial application in the new personal communication services band from 1.85 to 2.2 GHz.

212

A Framework for a General Purpose Intelligent Control System for Particle Accelerators--Vista Control Systems, Inc., 134-B Eastgate Drive, Los Alamos, NM 87544; (505) 662-2484
Dr. Robert T. Westervelt, Principal Investigator
Mr. Peter N. Clout, Business Official
DOE Grant No. DE-FG05-94ER81897
Amount: $73,803

The tuning and control of particle accelerators is a time consuming and expensive task. The control problem, in general, is inherently non-linear and one to which conventional control methods cannot be satisfactorily applied. Advanced information technologies such as expert systems and neural networks have been applied separately to these problems with limited success. Few, if any, of these advanced information technologies have been applied for general use or in a manner usable by multiple accelerator installations. In Phase I existing neural network and expert system technologies will be coupled to provide a general purpose, intelligent control system. This approach offers a feasible solution to the complex control problems encountered in accelerator controls. These technologies will be integrated within the framework of an existing commercial, general purpose control system that is extensively used by the accelerator control community. Also, typical and realistic scenarios in accelerator control will be defined using a commercial accelerator modeling code that will be enhanced to incorporate realistic noise effects. These scenarios will be used as a test platform for the general purpose control framework being developed as part of this work.

Anticipated Results/Potential Commercial Applications as described by the awardee: A framework for intelligent control and monitoring of complex accelerator control scenarios that can be packaged and marketed as an advanced information tool as part of an existing accelerator control product is expected. The definition and implementation of realistic and typical control scenarios that can be used by other researchers for benchmarks to facilitate communications and research in this problem area will result from this work.

APPENDIX A

Alphabetical List of Awardees

Abacus Controls, Inc. *1*
Mr. George O'Sullivan, Business Official
80 Readington Road
Somerville, NJ 08876
(908) 526-6010

Acrion Technologies, Inc. *79*
Dr. William R. Brown, Business Official
9099 Bank Street
Cleveland, OH 44125
(216) 573-1187

ADA Technologies, Inc. *27, 62*
Dr. Michael D. Durham, Business Official
304 Inverness Way South
Suite 110
Englewood, CO 80112
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Colorado	17, 27, 29, 60, 62, 69, 78, 81, 82, 91, 96, 106, 125, 162, 191, 196
Connecticut	22, 45, 47, 63, 83, 121, 127, 160, 161, 164, 171, 187, 188, 189, 201
Delaware	2, 3, 18, 146
Florida	101
Iowa	28
Illinois	72, 128, 174
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References denote entry numbers

APPENDIX C

Proposal Submissions and Awards
Listed by States, Territories, and Possessions

State	Number Submitted	Number Selected
Alabama	26	1
Alaska	2	0
Arizona	38	4
Arkansas	15	0
California	439	51
Colorado	111	16
Connecticut	91	15
Delaware	16	4
District of Columbia	1	0
Florida	56	1
Georgia	13	0
Hawaii	4	0
Idaho	13	0
Illinois	62	3
Indiana	3	1
Iowa	14	1
Kansas	4	0
Kentucky	6	0
Louisiana	43	1
Maine	12	1
Maryland	80	2
Massachusetts	251	37
Michigan	46	4
Minnesota	19	2
Mississippi	1	0
Missouri	14	0
Montana	14	0
Nebraska	2	0
Nevada	6	0
New Hampshire	13	0
New Jersey	72	7
New Mexico	67	8
New York	101	6
North Carolina	28	3
North Dakota	7	1
Ohio	72	2
Oklahoma	24	0
Oregon	29	7
Pennsylvania	61	6
Puerto Rico	1	0
Rhode Island	4	0
South Carolina	4	0
South Dakota	2	0
Tennessee	47	4
Texas	113	5
Utah	44	4
Vermont	10	2
Virginia	97	7
Washington	55	5
West Virginia	2	0
Wisconsin	16	1
Wyoming	5	0

Although eligible in each case to participate, there were no submissions from the Virgin Islands, the Commonwealth of the Northern Mariana Islands, or the Trust Territory of the Pacific Islands.

APPENDIX D

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SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0559)

U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585
August 8, 1994

SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM
(PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0559)

As a former chairman of the SBIR Application Score Verification Panel that had been appointed to evaluate Phase II grant applications for the SBIR program, I am familiar with the Panel's evaluation procedures and its methodology. I believe that the Panel has proceeded in accordance with applicable laws and regulations, that the evaluation was thorough and equitable, and that the information presented formed a sound basis for selection. This statement describes the procurement and sets forth my selection decision.

Procurement Description

The Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564), requires that each Federal agency with an extramural research or research and development budget exceeding $100 million establish an SBIR program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies over the 18 years of the program are as follows:

Fiscal Year	SBIR Set Aside (%)
1983	0.2
1984	0.6
1985	1.0
1986-1992	1.25
1993-1994	1.5
1995-1996	2.0
1997-2000	2.5

Public Law 97-219 also prescribes that the SBIR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the SBIR program. This phase will have a period of performance which is typically six months in duration. Awards during this phase will be up to $75,000. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $600,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-SBIR funded Federal contracts for products or services intended for use by the U.S. Government.

On December 8, 1992, the Department of Energy (DOE) issued its eleventh annual program solicitation for Phase I SBIR grant applications. We received 1999 applications in response to that solicitation; and on July 2, 1993, we selected 171 applications for Phase I funding, of which 168 proceeded to grants on September 8, 1993.

The Phase II SBIR program competition is limited to successful Phase I awardees. Under DOE procedures, grant applications for Phase II could be submitted at any time when it was deemed that sufficient progress had been attained under Phase I to justify the effort to be proposed for further development under Phase II. Applicants who wanted to maintain project funding continuity from Phase I to Phase II were asked by DOE to submit their applications not later than February 8, 1994, whereas the submission deadline for proposers not seeking to preserve project continuity was May 23, 1994. Based on the 168 Phase I awards, 42 Phase II applications were submitted by the February 8, 1994, deadline. From this submission, 17 were selected for Phase II awards in March 1994.

This current selection is made from applicants not seeking to preserve project continuity and from those applications that were received by February 8, 1994, but not yet funded. Of the group, 114 were received by the May 23, 1994 deadline, and 25 were not funded from the earlier submissions, for a total of 139 applications eligible for funding at this time.

Selection Criteria

Selections for Phase II awards were made on scientific and technical merit and commercial potential based upon the criteria listed below. Criterion 1 is given twice the weight of each of the other criteria. The six criteria are as follows:

1. The scientific/technical quality of the proposed research or R&D with special emphasis on its degree of innovation.

2. The qualifications of the Principal Investigator and other key personnel to carry out the proposed work and the level of adequacy of available or obtainable instrumentation and facilities.

3. The anticipated benefits, technical and/or economic, of the proposed research, with special emphasis on the likelihood that the project will attract further funding for product or process development after the SBIR support expires.

4. The degree to which the Phase I objectives were met at the time of Phase II grant application submission.

5. The soundness and level of adequacy of the Phase II proposed work plan to meet the problem or opportunity.

6. The commercial potential of the proposed research or R&D as evidenced by (a) the small business concern's record of commercializing SBIR or other research, (b) the existence of Phase II funding commitments from private sector or non-SBIR funding sources, (c) the existence of Phase III follow-on funding commitments for the subject of the research, and (d) the presence of

other indicators of commercial potential of the idea.

Criteria 1 through 5 ensure that award decisions will be based primarily on scientific and technical merit. Criterion 6 on commercial potential is new this year and was added to conform to the requirements of P.L. 102-564.

In all applications selected for awards, it was demonstrated that a minimum of one-half of the funded research or analytical effort would be performed by the applicant organization.

Selection Rationale

A Technical Project Manager (TPM) was appointed for each of the Phase I projects resulting from successful Phase I applications. Expert reviewers including DOE Laboratory personnel, university professors, and private industry personnel were selected with the help of the TPM, and they evaluated applications against criteria 1 through 5 and 6d. The TPM then scored applications based on these reviews. An SBIR Application Score Verification Panel, consisting of DOE staff and other technical personnel, was established to ensure relative uniformity of scoring across the board for these criteria and to assure that scores were based predominantly on meaningful technical reviews. The Panel was also chartered to ensure that there was consistency of scoring both within and between topics.

Criteria 6a, 6b, and 6c were evaluated by Panel members based on (non-technical) information provided in the grant applications, and a score was assigned for each of these criteria. The scores for 6a, 6b, 6c, and 6d were combined, with equal weight for each, to arrive at a single score for criterion 6. Then each application was assigned a total score based on the weighting described in the beginning of the previous section. Finally, the Panel ranked the 139 applications in order of their total scores.

I have looked at the evaluation documentation presented by the TPMs. I have also carefully reviewed the recommendations of the SBIR Application Score Verification Panel and have agreed that the evaluations of the reviewers, the scoring of the TPMs, and the recommendations of the Panel provided valid bases upon which to make a selection. Therefore, based on the ranking of the Panel, I have selected 46 applications for negotiation for award. This brings the total number of Phase II applications selected for negotiation to 63 including the 17 selections made in March 1994. Included in the 63 applications are all those which were within two points of the highest possible total score. The remainder was selected from among applications that were rated three points below the highest possible total score on the basis of program balance. It is my view that these applications represent outstanding technical quality and attest to the commitment of the SBIR program to excellence and to the development of high technology in the small business sector.

Samuel J. Barish

Samuel J. Barish
SBIR Program Manager
Date: 8/8/94

Attachments:
Appendix A: Listing of applications selected for negotiation for award.
Appendix B: Project summary of each application.

DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1994 PHASE II AWARDS

Company	Project Title
ADA Technologies, Inc. 304 Inverness Way South, Suite 110 Englewood,.CO 80112	Real-Time Continuous Analysis of Total and Elemental Mercury
ADA Technologies, Inc. 304 Inverness Way South, Suite 110 Englewood, CO 80112	A Laboratory/Field Workstation for Science Education
*ADA Technologies, Inc. 304 Inverness Way South, Suite 110 Englewood, CO 80112	Non-Toxic Additives for Improved Fabric Filter Performance
Advanced Fuel Research, Inc. 87 Church Street East Hartford, CT 06108	An Instrument for In-Situ Analysis of Carbon in Fly Ash
Advanced Fuel Research, Inc. 87 Church Street East Hartford, CT 06108	On-Chip Infrared-Spectral Sensors by Superconducting Detector Arrays
Advanced Fuel Research, Inc. 87 Church Street East Hartford, CT 06108	An In-Situ Particle Sensor for Metal Forming Processes
Advanced Fuel Research, Inc. 87 Church Street East Hartford, CT 06108	Production of Carbon Materials from Lignin
*Advanced Refractory Technologies, Inc. 699 Hertel Avenue Buffalo, NY 14207	Porous Aluminum Nitride Part Fabrication to Support Advanced Battery Development

*Project provided with funding continuity following application submission by February 8, 1994

Advanced Resources International, Inc. 165 South Union Boulevard, Suite 816 Lakewood, CO 80228	Application of Exploration and Advanced Well Completion Technology to High Productivity Coalbed Methane Fairways
Altex Technologies Corporation 650 Nuttman Road, #114 Santa Clara, CA 95054	Reconstitution of Beneficiated Coal Using the Biobinder Process
American Superconductor Corporation 2 Technology Drive Westborough, MA 01581	Oxide Dispersion Strengthened Silver for Use in High-Temperature Superconductor Composite Wires
Ashwin-Ushas Corporation, Inc. 206 Ticonderoga Boulevard Freehold, NJ 07728	Flexible Electrochromic Window Materials Based on Poly(diphenylamine) and Related Conducting Polymers
Bend Research, Inc. 64550 Research Road Bend, OR 97701-8599	Composite Plasma-Polymer Membranes
*Bend Research, Inc. 64550 Research Road Bend, OR 97701-8599	A Novel Process for the Removal of Nitrogen from Nitrogen-Containing Natural Gas: Development of Water-Based Absorbents
*BioTraces, Inc. 7986 Lakecrest Drive Greenbelt, MD 20770	Development of a High Spatial Resolution Neutron Detector
Chemat Technology, Inc. 19365 Business Center Drive Suite 8 Northridge, CA 91324	Capacitive Energy Storage Using High Surface Area Hafnium Compounds
*Composite Technology Development, Inc. 2400 Central Avenue, Suite H Boulder, CO 80301	Radiation Resistant Radio Frequency Feedthrough Insulators for Fusion Applications

*Project provided with funding continuity following application submission by February 8, 1994

Creare, Inc. P.O. Box 71 Hanover, NH 03755	Helium-Cooled Divertors with Low Pumping Power and Simple Fabrication Techniques
Creare, Inc. P.O. Box 71 Hanover, NH 03755	A High-Performance Cryogenic Heat Exchanger
*DULY Research, Inc. 1912 MacArthur Street Rancho Palos Verdes, CA 90732	A Microwave Power Combiner for a Cluster Klystron
Energy and Environmental Research Corporation 28 Mason Irvine, CA 92718	Multiple Air Pollutant Emissions Removal by the Use of a Single Chemical Additive
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06813	Demonstration of an Integrated Carbon Dioxide/Thermal Management System for Carbonate Fuel Cells
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06813	Advanced Ceramic Fibers for a Carbonate Fuel Cell Matrix
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06813	A Carbonate Fuel Cell Monolith for Low-Cost and High Power Density Operation
ERC, Inc. P.O. Box 417 205 Research Park Drive Tullahoma, TN 37388	Remote Sensing Diagnostics for Magnetohydrodynamic and Power System Environments
*ERC, Inc. P.O. Box 417 205 Research Park Drive Tullahoma, TN 37388	A T-Layer Alternating Current Generator

*Project provided with funding continuity following application submission by February 8, 1994

Gumbs Associates, Inc. 11 Harts Lane East Brunswick, NJ 08816	Advanced Window Materials Based on Conducting Polymer/Sol-Gel Ceramic Composites and Tungsten Oxide Coatings
*Haimson Research Corporation 3350 Scott Boulevard, Building 60 Santa Clara, CA 95054-3122	A 17 Gigahertz High-Gradient Accelerator Structure for a Picosecond Bunch, 30 MeV Electron Source
Hi-Z Technology, Inc. 6373 Nancy Ridge Drive San Diego, CA 92121-2247	Multilayer, Quantum Well Layer Film Thermoelectrics
IGC Advanced Superconductors, Inc. 1875 Thomaston Avenue Waterbury, CT 06704	Methods of Improving Internal-Tin Niobium-Tin for Fusion Applications
ISM Technologies, Inc. 9965 Carroll Canyon Road San Diego, CA 92131	Low Temperature Deposition of Titanium Nitride
Karta Technology, Inc. 1892 Grandstand San Antonio, TX 78238	Advanced Nondestructive Evaluation for Quality Assurance of Divertor Plate Armor Tiles in Plasma Fusion Reactors
Lanxide Corporation P.O. Box 6077 1300 Marrows Road Newark, DE 19714-6077	An Innovative Approach for the Formation of Silicon Carbide/Silicon Carbide Composites
*Lightwave Electronics Corporation 1161 San Antonio Road Mountain View, CA 94043	Mode-Locked Pulse Amplifiers for Photocathode Illumination
*LSR Technologies, Inc. 898 Main Street Acton, MA 01720	A Novel Hot Gas Cleanup System for Biomass Power Technology

*Project provided with funding continuity following application submission by February 8, 1994

Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706	Doping Silicon Carbide to Produce High Thermal Conductivity Silicon Carbide/Silicon Carbide Composites
Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706	Ceramic Filters for Ultrafine Particulate Separation in Combustion Gas Environments
MDS Company 1955 Mountain Boulevard, Suite 101 Oakland, CA 94611	Development of a 100 Megawatt X-Band Relativistic Klystron Amplifier
Mission Research Corporation 735 State Street P.O. Drawer 719 Santa Barbara, CA 93102-0719	Magnetron Arrays for Linear Colliders
Montec Associates, Inc. P.O. Box 4182 Butte, MT 59702	A Testing Process to Define Electrode Current Wear Mechanisms and Develop Improved Electrodes
*Nanoptics, Inc. 3014 Northeast 21st Way Gainesville, FL 32609	A High Resolution Scintillator-Based Neutron Detector
Northwest Fuel Development, Inc. 4064 Orchard Drive Lake Oswego, OR 97035	A Pressure Swing Adsorption/Temperature Swing Adsorption Process for Nitrogen Rejection from Natural Gas
Omega-P, Inc. 2008 Yale Station New Haven, CT 06520	A Modified Inverse Free-Electron-Laser Accelerator
Orincon Corporation 9363 Towne Centre Drive San Diego, CA 92121	A Neural Network-Based Disruption Alarm

*Project provided with funding continuity following application submission by February 8, 1994

Physical Optics Corporation 2545 West 237th Street, Suite B Torrance, CA 90505	Novel Spectrally Selective Window Films Based on Multiplexed Holography
Physical Sciences, Inc. 20 New England Business Center Andover, MA 01810	Measurement of Mercury and Other Trace Metals in Combustion Gases
*Plasma Processes, Inc. P.O. Box 14524 Huntsville, AL 35815-0524	Dense, High Conductivity, Copper/Aluminum/Beryllium Functionally Gradient, Plasma Facing Components
*Praxis Engineers, Inc. 852 North Hillview Drive Milpitas, CA 95035	Use of Supervisory Control Techniques for Optimization of Environmental Emissions in Power Plants
Q-Chem, Inc. 7520 Graymore Road Pittsburgh, PA 15221	A Rapid Calculation of the Coulomb Field in Large Molecules
*Quantum Magnetics, Inc. 11578 Sorrento Valley Road San Diego, CA 92121	An Intensity and Position Monitor for Particle Beam Diagnostics
Radiation Monitoring Devices, Inc. 44 Hunt Street Watertown, MA 02172	An Integrated Video and Gamma Ray Imaging System for Robots in Nuclear Environments
REB Research and Consulting 25451 Gardner Oak Park, MI 48237	Improved Coated-Metal Hydrogen Extraction Membranes
*SAGE Corporation P.O. Box 278 Brett and Bowser Road Piscataway, NJ 08855	The Feasibility of Using Squeeze Roll Coating to Form Sol-Gel Derived Layers for Switchable Electrochromic Windows

*Project provided with funding continuity following application submission by February 8, 1994

Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143	A High Repetition-Rate, High Power, All-Solid-State Pulsed Driver for Electrodeless Inductive Thrusters
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143	A Passive Optical Monitor for Tokamak Plasma Inhomogeneities
Sigma Labs, Inc. 10960 North Stallard Place Tucson, AZ 85737	A Thermally Stable Polypropylene Hybrid Film for Electrical and Packaging Applications
Sorbent Technologies Corporation 1935 East Aurora Road Twinsburg, OH 44087	Catalytic Production of Elemental Sulfur from Sulfur Dioxide-Containing Gas Streams
*Spinheat Limited 1222 Bronson Road Fairfield, CT 06430	Development of a Rotary Combustor for Refiring Pulverized Coal Boilers
*Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545	Superconducting Wire with a Built-in Niobium Surface Coating to Limit Interstrand Eddy Currents in Cables
Ultramet 12173 Montague Street Pacoima, CA 91331	Coated Micrograin Carbides for Wear Resistance
Umpqua Research Company P.O. Box 791 Myrtle Creek, OR 97457	An Oceanographic Carbon Dioxide Sensor
Videodiscovery, Inc. 1700 Westlake Avenue North Suite 600 Seattle, WA 98109	Living On Earth: A Multimedia-Based Learning Environment for the Earth Sciences

*Project provided with funding continuity following application submission by February 8, 1994

8

Vortec Corporation
3770 Ridge Pike
Collegeville, PA 19426

Glass Ceramic Construction Tiles from Coal-Fired Boiler Ash

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*Project provided with funding continuity following application submission by February 8, 1994

DOE/ER-0628

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE II AWARDS

1994

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager
Washington, D.C. 20585

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PREFACE

The SBIR program enables DOE to obtain effective, innovative solutions to important problems through the private sector, which has a commercial incentive to pursue the resulting technology and bring it to the marketplace. The growing number of awardees, many of them started in business in response to SBIR solicitations, is becoming a significant resource for the solution of high risk, high technology problems for the Department. As detailed below, this publication describes the technical efforts and commercialization possibilities for SBIR Phase II awards in 1994. It is intended for the educated layman, and may be of particular interest to potential investors who wish to get in on the ground floor of exciting opportunities.

The Federal SBIR Program

This program, now completing its twelfth year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Eleven Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over $100 million. The agencies were required to set aside 1.5% of those budgets in Fiscal Year (FY) 1994 to fund SBIR projects. (This amounted to about $53 million in FY 1994 for the Department of Energy.) Each agency solicits proposals from small science- and technology-based US firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to $75,000 in FY 1993. Phase II is the principal research or R&D effort, and the awards were as high as $600,000 in FY 1994 for work to be performed in a period of up to two years. Phase III is the commercial application of the research or R&D effort by the small businesses using non-Federal funding or, alternatively, it may involve follow-on non-SBIR Federal contracts for products or services desired by the Government. The program continues to strengthen the role that small, innovative firms play in meeting the Nation's research and development needs and in commercialization of ideas developed through federally funded R&D.

Phase II Awards for FY 1994

Contained in this booklet are abstracts of the Phase II awards made in FY 1994 under the DOE SBIR program.

DOE received 1999 grant applications in response to its annual solicitation, and on July 2, 1993, 171 were selected for Phase I funding. The Phase II SBIR program competition was limited to the 168 projects that subsequently proceeded to Phase I awards.

Applicants desiring to maintain project funding continuity from Phase I to Phase II were invited to submit their grant applications to DOE not later than February 8, 1994, approximately 6 weeks before the end of their Phase I grants. Forty-two Phase II applications were submitted by that date, and 17 were selected for Phase II awards; those projects were then able to continue without funding interruption between Phases I and II. The deadline for the submission of Phase II applications for applicants not seeking to maintain project funding continuity was May 23, 1994. From the 114 applications submitted by this date and from the 25 unfunded applications from the February 8, 1994, submissions, 46 were selected for Phase II awards. The 63 Phase II projects described in this book consist of these 46 projects and the 17 projects that were funded from the February 8 submissions. The listed amount of each award, in many instances, is subject to completion of award negotiations.

The DOE SBIR Program

DOE's FY 1993 annual Solicitation contained 37 technical topics in the areas of basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, energy efficiency and renewable energy, fossil energy, and nuclear energy. There is keen competition because awards are made solely on the basis of scientific and technical merit, regardless of the technical topic.

As a measure of the program's success, eleven DOE SBIR projects have received R&D-100 Awards from Research and Development Magazine, which selects the 100 most significant technical products each year. In addition, five DOE awardees were chosen among the 500 fastest-growing American private companies, in the December 1991 issue of Inc. Magazine, based on their growth in sales. Also, from the first six cycles of awards (Phase II projects completed between 1986 and 1991), DOE SBIR winners have already received approximately $260 million in Phase III funding, which is about 60% larger than the SBIR support they were given. This number is expected to grow significantly in the next few years.

The DOE SBIR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. In the first year of Phase II awards (1984), a system was devised and implemented that allowed Phase I awardees who felt they were ready to submit their Phase II applications before their Phase I grants ended, to do so. For each of the eleven years in which Phase II awards have been made, such grantees who were chosen for Phase II funding were able to begin their projects without an interruption in funding. Since 1984, about 40 per cent of the Phase II awardees have had continuous funding between Phases I and II.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, DOE has instituted a special training project, supported by non-SBIR funds. For the past five years, successful Phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participation in the 1991 project, the SBIR companies have already received more than $14 million for commercialization of their SBIR research, with a projected royalty stream from option agreements of an additional $24 million over the next three to five years. About 43% of the firms that completed the project have received further funding for their work. Sources of capital that wish to consider participation in future programs should contact Dr. Robert Berger, U.S. Department of Energy SBIR Program, ER-16, Washington, D.C. 20585, 301-903-3054.

Samuel J. Barish
SBIR Program Manager
US Department of Energy
Washington, DC 20585

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ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY FOR FOSSIL ENERGY

1

Non-Toxic Additives for Improved Fabric Filter Performance--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Ms. C. Jean Bustard, Principal Investigator
Dr. Judith A. Armstrong, Business Official
DOE Grant No. DE-FG02-93ER81500
Amount: $600,000

Title III of the Clean Air Act Amendments of 1990 includes a comprehensive plan to achieve significant reductions in emissions of hazardous air pollutants from major sources. The mandate to reduce air toxics will require upgrading particulate control equipment since many of the toxic metals exist as fine particles. One of the means to increase collection efficiency and decrease outlet emissions from fabric filters is to improve the cohesive characteristics of the dust. Dual conditioning with NH_3 and SO_3 is a proven means of artificially enhancing the cohesivity of flyash and is commercially available for use with both electrostatic precipitators and fabric filters; however, there are health, safety, and hazardous waste issues associated with them. This project will optimize and demonstrate the performance of new, non-toxic additives as flue gas conditioning agents to improve fabric filter performance. The successful additives will be demonstrated at full-scale, on flue gas from an operating coal-fired boiler. These additives will decrease outlet emissions, reduce pressure drop and associated energy requirements, and be less expensive than current technologies. Phase I successfully demonstrated that four new, non-toxic additives reduced outlet emissions by a factor of ten and resulted in fabric filter performance similar to that produced by the SO_3/NH_3 conditioning. An economic analysis showed that use of these additives as flue gas conditioning agents is significantly less expensive than use of SO_3/NH_3. This project will 1) continue the development of the additives in laboratory evaluations; 2) evaluate the most successful additives in actual flue gas at a bench-scale to identify and solve any problems that actual flue gas may pose; and 3) demonstrate the performance of the additives on a full-scale baghouse compartment.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful development of these additives should result in a cost effective, alternative conditioning system that will reduce particulate air toxic emission and reduce energy costs by improving baghouse performance. This technology should be applicable not only to coal-fired power plants, but also to emissions from incinerators, industrial boilers, process industries, minerals processing and smelting facilities, refineries, metal fabrication shops, and other thermal processing sites. A commercialization partner who will market the new additive has been identified and recruited to the Phase II project team.

2

Real-Time Continuous Analysis of Total and Elemental Mercury--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Mr. Richard J. Schlager, Principal Investigator
Dr. Judith A. Armstrong, Business Official
DOE Grant No. DE-FG02-93ER81501
Amount: $600,000

The overall objective is to develop and test a continuous emissions monitoring (CEM) system that will quantify the mercury content of flue gas. The Phase I project successfully demonstrated three key components of the CEM system: 1) a sensitive mercury detector based on ultraviolet absorption spectrometry, 2) a mercury species converter, and 3) a CEM calibration system. The minimum level of detection of the mercury detector was found to be 0.2 $\mu g/m^3$, which is well below the original target established for the project. The mercury species converter effectively transformed two mercury species surrogates--mercuric chloride and dimethyl mercury--to elemental mercury. Finally, a calibration system based on permeation tubes and diffusion vials was used to produce reference standards for evaluating the mercury detector and converter. In Phase II, a prototype CEM system will be fabricated and field demonstrated. The CEM system will include a probe, valve box, sample line, converter, analyzer, and calibrator. The system will be field tested and the measurement results will be compared with samples collected using manual sampling techniques. Real-time measurements of mercury emissions will assure facility operators, regulators, and the public that emissions limitations are within compliance and that control systems are operating at peak efficiency.

Anticipated Results / Potential Commercial Applications as described by the awardee: Mercury is emitted as a pollutant from coal and oil combustion, municipal waste combustion, medical waste incineration, and a variety of other thermal treatment processes. A current analyzer market exists for MSW facilities and for researchers who are developing systems that control mercury emissions. A substantial future market is expected as a result of EPA activities aimed at controlling air toxic emissions from combustion facilities.

3

An Instrument for In-Situ Analysis of Carbon in Flyash--Advanced Fuel Research, Inc., 87 Church Street, East Hartford, CT 06108; (203) 528-9806
Dr. Anthony S. Bonanno, Principal Investigator
Dr. Peter R. Solomon, Business Official
DOE Grant No. DE-FG05-93ER81509
Amount: $599,845

An instrument capable of making on-line, in-situ measurements of the residual carbon content in flyash would be a valuable asset in the optimization of power plant efficiency and in achieving pollution control goals. Current instruments available to measure the residual carbon in flyash are based on extractive point samples. Measurements of this type are relatively slow, are prone to inaccuracies, and require significant maintenance and sample-handling instrumentation. This project will develop an on-line carbon in flyash monitor based on in-situ infrared emission measurements. Measurements made during Phase I demonstrated that the infrared spectral emissivity of flyash can be correlated to the residual carbon content in the range of interest. Additionally, data collected during a field test at a pilot-scale combustor demonstrated that the emissivity measurements could be made in-situ on a realistic facility, and that the spectral emissivity could be correlated to the carbon content. The Phase II project will address the detailed design and calibration of a prototype instrument using theoretical simulations and experimental measurements on both pilot-scale and utility-scale facilities. Initial testing and calibration will be performed using a flexible prototype system which will allow for optimization of both the optical configuration and the calibration software. Then a dedicated prototype will be designed and built around new, innovative FT-IR components specifically designed for use in harsh industrial environments. The design of the dedicated prototype will address all aspects required for a permanently installed instrument. The dedicated prototype will then be subjected to shakedown tests at both pilot-scale and utility-scale facilities.

Anticipated Results / Potential Commercial Applications as described by the awardee: An on-line instrument to measure the carbon content in flyash at coal-fired facilities should allow the development of control technology to optimize NO_x reduction processes while maintaining high combustion efficiency. This should provide economic benefits in the form of reduced fuel costs and reduced requirements for post-combustion treatment of pollutant species. Additionally, the capability to reduce pollutant emission levels could improve the environmental acceptability of coal-fired power generation.

4

Ceramic Filters for Ultrafine Particulate Separation in Combustion Gas Environments--Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706; (602) 574-1980
Dr. R. O. Loutfy, Principal Investigator
Dr. J. C. Withers, Business Official
DOE Grant No. DE-FG02-93ER81481
Amount: $600,000

Phase I demonstrated the feasibility of using novel hollow fiber composites with controlled porosity characteristics (i.e. uniform, straight channeled pores of variable diameter) to develop filters with lower pressure drops, higher particle collection efficiencies, and higher strength values than currently available with commercial filters. A second type of filter was also developed which could be inexpensively fabricated by the chemical vapor reaction of graphite to silicon carbide, followed by deposition of coatings to provide greater strength compared to commercial filters. Parameters controlling the filtration capabilities of both filter types were identified. In Phase II, the development of the two filter materials will continue with the objective of meeting material requirements for both low and high temperature filters. A corrosion resistant oxide matrix will be developed, the toughness of the oxide matrix will be enhanced using in-situ whiskerization, and a processing technique will be developed to produce prototype candle filters. The filters will be extensively tested in order to characterize their filtration capabilities, microstructure, and hot gas strength in a simulated gas environment.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that both types of filters should find application in systems requiring ceramic filters for high temperature, ultrafine particulate separation. There exists a substantial market for such filters in the coal combustion industry alone. In addition, the novel hollow fiber composite filters, where porosity characteristics can be precisely controlled, could find additional applications where controlled porosity is critical, including in nuclear weapons systems.

5

Measurement of Mercury and Other Trace Metals in Combustion Gases--Physical Sciences, Inc., 20 New England Business Center, Andover, MA 01810; (508) 689-0003
Dr. Lawrence G. Piper, Principal Investigator
Mr. Michael L. Finson, Business Official
DOE Grant No. DE-FG02-93ER81528
Amount: $599,998

The 1990 Clean Air Act Amendments (CAAA) targeted mercury and ten other trace metals for regulation with implementation expected by 1996. The objective of this project is to design, develop, test, and calibrate a compact, portable instrument for monitoring concentrations of mercury and other hazardous heavy metals in coal-fired power plant flue gases at sub-parts per billion (ppb) levels. The approach exploits active nitrogen energy transfer (ANET) excitation of atomic fluorescence using dielectric-barrier (D-B) discharge technology to generate the active nitrogen at atmospheric-pressure. Because ANET excitation populates only one emission line of mercury at 253.7 nm, the ANET fluorescence spectrum is exited efficiently and can be analyzed with instrumentation of modest resolution. Phase I demonstrated that: mercury in the gas phase could be detected with a sensitivity limit below 100 parts per trillion in the presence of simulated flue gas, mercury could be detected at ppb levels in gaseous samples taken from a coal combustor, mercury compounds on particulates could be detected, and mercuric chloride can be detected sensitively and differentiated from elemental mercury. In Phase II, a mercury monitor based upon ANET technology wil be developed with complete design and component specifications for a second-generation, or beta, commercial prototype, and the ANET technology will be extended to detect other toxic heavy metals, such as Se, As, and Cr. First, key issues, (including sampling, detection protocols, and calibration techniques) will be resolved during the design and development of the first-generation, or alpha, prototype, and an alpha-prototype mercury monitor will be fabricated. Then extensive field testing will begin in a combustion facility and conclude with several months of field testing at a local power plant. The third task is the design of the beta prototype. Finally, the ANET technology will be extended to the detection of other toxic heavy metals.

Anticipated Results / Potential Commercial Applications as described by the awardee: At the conclusion of this project the ANET technique should have been developed to the point that the beta-prototype design can be used to fabricate and begin immediate commercialization of a sensitive, real-time mercury monitor for power plant flue stacks. The monitor should measure quantitatively the mercury content in combustion gases. Its market could include electric utility power generation plants, large industrial combustion systems, Superfund cleanup sites, industrial and government waste sites, municipal waste incinerators, and mercury processing facilities. At least one detector will be required at each of these sites which number in the tens of thousands.

3

6

Catalytic Production of Elemental Sulfur from Sulfur Dioxide-Containing Gas Streams--Sorbent Technologies Corporation, 1935 East Aurora Road, Twinsburg, OH 44087; (216) 425-2354
Mr. Sidney G. Nelson, Principal Investigator
Mr. Sidney G. Nelson, Business Official
DOE Grant No. DE-FG02-93ER81548
Amount: $575,000

A new process for converting SO_2 directly to elemental sulfur was developed in Phase I. The new technology is a one-step process, based on a new catalyst and is expected to be a low-cost alternative to a modified Claus plant. The first objective of this project is to optimize this new process by examining how changes in the composition of the entering-gas, the presence of impurities in the gas, and the long-term use of the catalyst affect process performance. The second objective is a pilot plant demonstration at DOE's copper oxide flue-gas desulfurization (FGD) pilot facility in Pennsylvania in which an SO_2-rich regenerator off-gas stream will be continuously treated. During Phase I, elemental sulfur yields were increased from about 50 percent to over 95 percent. In Phase II, nine tasks will be performed to increase the sulfur yields further, possibly to 100 percent: Task 1 will involve additional laboratory studies to optimize the developed process; Task 2 will consist of long-term laboratory runs; Tasks 3 and 4 will involve the development of suitable process equipment; a skid-mounted, pilot-plant demonstration system will be designed, constructed, and presented in Tasks 5, 6 and 7; in Task 8, the system will be moved to the copper Oxide FGD pilot facility where it will be installed and tested; and in Task 9, a cost study will compare the costs of the new technology with those of a modified Claus plant.

Anticipated Results / Potential Commercial Applications as described by the awardee: The new process is a generic technology that should be applicable in many different settings. Success on the project could have a major impact on the development, economics, and ultimate use of regenerable flu-gas desulfurization and coal gasification processes. If successful, the new technology could also find use in various petroleum and natural gas, chemical, and iron-making applications.

7

Glass Ceramic Construction Tiles from Coal-Fired Boiler Ash--Vortec Corporation, 3770 Ridge Pike, Collegeville, PA 19426; (610) 489-2255
Dr. John F. Mooney, Principal Investigator
Dr. James G. Hnat, Business Official
DOE Grant No. DE-FG02-93ER81555
Amount: $599,861

The objective of this project is to develop an advanced melting/forming process for the manufacture of high quality, low cost, glass-ceramic tiles from coal fired boiler flyash and other industrial waste materials. The melting/forming process represents a major technology advancement for the manufacture of floor, wall, and roofing tiles. It has the potential of significantly reducing the costs, energy consumption, and waste associated with existing tile manufacturing operations. Phase I demonstrated the feasibility of using boiler flyash as a primary feedstock in the production of ceramic tiles with advanced glass melting/forming technology. Using laboratory and pilot scale melting operations, suitable feedstock compositions were developed and prototype tiles manufactured for evaluation against existing ceramic tile quality control criteria. Prototype tiles were evaluated using existing tile industry standards and were found to be significantly superior in terms of breaking strength, porosity, dimensional tolerance, dimensional stability, and thermal cycling properties. Cost estimates of the new manufacturing process indicated a potential savings of over 50% relative to existing manufacturing operations. In Phase II, pilot scale manufacturing systems will be developed to demonstrate the capability to form, heat treat, glaze, and decorate glass-ceramic tiles on an industrial scale. Several waste generators and companies involved in the manufacture of glass, ceramic tiles, or tile producing equipment will participate in the Phase II development effort on a cost sharing basis.

Anticipated Results / Potential Commercial Applications as described by the awardee: In Phase III, an integrated commercial demonstration should serve as the basis for introducing the technology to the entire ceramic tile industry for manufacturing ceramic based building products from recycled boiler ashes and industrial wastes. Successful development of this technology could also mitigate major problems associated with disposal of boiler ash and industrial wastes, saving an estimated two million cubic yards per year of diminishing landfill space.

INCREASED COAL UTILIZATION, ADVANCED COMBUSTION, AND CO_2 REDUCTION TECHNIQUES

8

A High Temperature (T-Layer) Alternating Current Generator--ERC, Inc., P.O. Box 417, 205 Research Park Drive, Tullahoma, TN 37388; (615) 455-9915
Dr. Y. C. L. Susan Wu, Principal Investigator
Mr. Richard Lin, Business Official
DOE Grant No. DE-FG05-93ER81557
Amount: $599,901

This project consists of the development of a high temperature layer (T-Layer) AC generator, which is an innovative idea for a compact, light weight power supply capable of direct production of high capacity, AC electric power. The T-Layer AC generator works according to the standard principles of electromagnetics. In the power system, a high temperature layer of ionized gas, the T-Layer, is created by external excitation, e.g., electric discharge. The T-Layer formed by the energy excitation is a highly ionized stratified layer with extremely high electrical conductivity. This layer is driven through a channel by the action of flow pressure. The channel is situated in a magnetic field, and a potential difference develops across the channel. The channel-magnet forms a generator that can produce useful electrical power according to standard principles of electromagnetic induction. AC power can be generated by repetition of the T-Layer flow through the channel. The T-Layer AC generator has definite advantages over contemporary power systems that make it an attractive power source for special and high power density type applications. The T-Layer generator is simple in its construction and operation, has uncomplicated power consolidation and isolation needs, and can operate with a fluid of low bulk temperature with or without ionization seed. A very attractive feature for this system is its high power density and high efficiency. These traits indicate that a compact, light weight system can be developed. This project will determine criteria for the T-Layer AC power system and will focus on completing the necessary laboratory proof-of-principle experiments to demonstrate the concept. First, theoretical and experimental studies will determine component design specifications. Then, a laboratory scale T-Layer AC generator will be assembled and tested to demonstrate this power process and evaluate its potential as a commercial system. In parallel, conceptual studies will determine applications for this system in the field. The necessary factual information on the T-Layer AC generator will be gathered to allow the basis for a Phase III program directed at commercialization.

Anticipated Results/Potential Commercial Applications as described by the awardee: Commercial application is expected where reliable, efficient, high power, compact electrical generators are needed. A T-Layer power system can readily meet the needs of mobile platforms, such as marine and airborne. It has generic application to large scale industrial power, as well as governmental and military needs. These include coupling to gas cooled nuclear reactors and a power source for advanced defense systems. The T-Layer principle should also be used in a fluid accelerator application; e.g., propulsion and hypersonic flow simulation.

9

Remote Sensing Diagnostics for Magnetohydrodynamic and Power System Environments--ERC, Inc., P.O. Box 417, 205 Research Park Drive, Tullahoma, TN 37388; (615) 455-9915
Dr. Y. C. L. Susan Wu, Principal Investigator
Dr. Y. C. L. Susan Wu, Business Official
DOE Grant No. DE-FG05-93ER81556
Amount: $600,000

Magnetohydrodynamic and power system environments pose significant problems for instrumentation and personnel protection. The large voltages, both absolute and common mode, and large magnetic fields found in such environments complicate the use of conventional instrumentation. The objective of this project is to develop specialized remote sensing diagnostics that would provide enhanced electrical isolation and increased noise immunity while being more reliable and less costly than current technology. Phase I research demonstrated the feasibility of the remote sensing approach by constructing a probe and using it to make voltage measurements on an operating magnetohydrodynamic power generator. Phase II includes three primary research areas needed to bring a line of remote sensors to the commercial market. The first addresses the optimization of the transmitter of the remote sensor and the development of a comprehensive array of transducers. In the second, appropriate power supplies for the remote transmitter will be developed. The third research area will investigate technologies for miniaturization and packaging. Concurrent with these technical research paths, studies will be conducted into the marketing and commercialization aspects necessary to plan a successful Phase III effort.

Anticipated Results / Potential Commercial Applications as described by the awardee: This research should provide small, highly reliable electrically isolated remote sensors for use in industrial utility type environments such as found around magnetohydrodynamic generators, standard electrical generators, arc incineration systems, plasma generators, etc. The probes could also have application to research areas in which high voltage generators are used.

10

A Testing Process to Define Electrode Current Wear Mechanisms and Develop Improved Electrodes--Montec Associates, Inc., P.O. Box 4182, Butte, MT 59702; (406) 494-2596
Mr. Lawrence C. Farrar, Principal Investigator
Mrs. Cynthia K. Farrar, Business Official
DOE Grant No. DE-FG03-93ER81535
Amount: $599,672

Wear characteristics for electrodes obtained from commercial plasma torch applications will be compared with bench scale results to delineate salient wear mechanisms and investigate electrode and materials design features that mitigate them. Bench scale experiments will be combined with small scale plasma torch experiments to provide a systematic, economic test methodology. The test methodology will be used to establish electrode failure processes and investigate novel and improved arc mode electrode materials and designs that will enhance their lifetime. Specific electrode concepts to be evaluated include the use of a porous electrode and diamond films as well as the use of specific electrode material alloys that reduce electrode wear for specific plasma torch applications and operating conditions. Although the work should develop a fundamental understanding of the relations between electrode wear and their applications, the project is designed to focus on product innovations which results in process improvement, entry of new products (or product line) into the market, and/or expanded applications and operating conditions. This work is motivated by the desire to increase the applications for plasma torch technology and to improve its economics.

Anticipated Results / Potential Commercial Applications as described by the awardee: A methodology to develop improved and novel electrode designs for plasma torches should result from this project. It should also produce a means to economically evaluate state-of-the-art materials for application as plasma torch electrodes. The process provides a cost effective means to develop novel and innovative plasma electrode materials. Commercial applications could include uses in the metallurgical industry and in hazardous waste remediation processes.

11

Development of a Rotary Combustor for Refiring Pulverized Coal Boilers--Spinheat Limited, 1222 Bronson Road, Fairfield, CT 06430; (203) 254-0340
Mr. Michael J. Virr, Principal Investigator
Mr. Michael J. Virr, Business Official
DOE Grant No. DE-FG05-93ER81515
Amount: $599,842

The objective of this project is to demonstrate the feasibility of using the Rotary Combustor (RC) to replace conventional pulverized coal burners as a means of reducing plant emissions on utility and industrial boilers. The RC consists of a slowly revolving, perforated drum in which a shallow bed of coal ash and limestone is held in suspension by substoichiometric air. Granular coal and limestone are introduced into the drum where coal is partially burned and limestone is calcined. The resultant fuel gas is then blown through a firetube where secondary air is added and nitrogen is fixed by disassociating the NO_x precursors before the gas is allowed into the combustion chamber. Combustion is then completed in a conventional flame. The RC is installed on the burner wall of the coal boiler to replace the existing burners and milling equipment, thus eliminating the power consumption of the mills and raising overall plant efficiency. Limestone is fed in with the coal to capture the sulfur in the rotary gasifier section, which is very effective as the temperature window is controlled. Thus, sulfur capture of over 90% is achievable. The RC incorporates a firetube which stages combustion, thereby reducing NO_x to significantly lower levels than other burners, that is, below 100 parts per million by volume. Therefore, the RC addresses both SO_x and NO_x reduction in the same burner. The Phase II objective is to complete the detailed design of a 6.8 mBTU/hour unit, then manufacture and test the RC on a commercial manufacturer's package boiler test rig. A test schedule has been drawn up in cooperation with the Pittsburgh Energy Technology Center in which it is intended to test the unit on both medium and high sulfur coal while simultaneously measuring both SO_x and NO_x, as well as the combustion performance indicator CO. A series of parametric tests will be carried out with professional emission monitoring. The RC will also be demonstrated to utilities, coal companies, and other interested parties.

Anticipated Results/Potential Commercial Applications as described by the awardee: The demonstration of the RC by firing into a package boiler with simultaneous low emissions of SO_x and NO_x should be a convincing demonstration of the burner. The successful development of the RC should offer utilities and industrial boiler users the opportunity of refiring existing coal-fired steam boilers with burners that should comply with Phase II of the Clear Air Act Amendment of 1990, while realizing a power gain. Both capital and running costs of the RC will be substantially less than current fuel gas desulfurization and $DeNO_x$ control of approximately $100/kw.

COAL BENEFICIATION AND TRANSPORT

12

Reconstitution of Beneficiated Coal Using the Biobinder Process--Altex Technologies Corporation, 650 Nuttman Road, #114, Santa Clara, CA 95054; (408) 982-2303
Dr. John T. Kelly, Principal Investigator
Dr. Mehdi Namazian, Business Official
DOE Grant No. DE-FG03-93ER81485
Amount: $599,393

For optimal beneficiation, coal must be finely ground to release the pyritic sulfur and ash inclusions. The resulting clean product is difficult to handle, transport, and store. By reconstituting the product through pelletization these difficulties can be overcome. However, excessive pelletization costs, and in particular binder costs, have limited this practice. The BioBinder process has been identified for the reconstitution of cleaned coal fines. This process uses special binder and processing conditions to create durable fuel pellets at low cost. In Phase I, the special binder and processing equipment were used to create and test BioBinder fuel pellets. Tests showed that the pellets were durable and could survive challenging weather conditions, including freeze and thaw cycles. In addition, the pellets were found to burn better than parent coal. Most importantly, very conservative economic analyses showed that the pellets are 28 percent lower in cost than parent coal. These results show the technical and economic feasibility of the BioBinder process. Phase II will attempt to demonstrate continuous pellet processing at a 4 tons-per-day capacity. In addition, the pellets will be tested in a 750,000 Btu/hr test stoker and a 650 HP commercial stoker. Based on the results of the tests, refined performance and economic analyses will be performed for a projected 1000 tons-per-day commercial scale system. Coal fines producers, sludge producers and equipment suppliers will assist in carrying out all of these efforts.

Anticipated Results/Potential Commercial Applications as described by the awardee: At the conclusion of the Phase II effort, equipment should be available to produce limited quantities of BioBinder pellets which can be used to demonstrate good durability and combustion characteristics for potential customers. The low cost pellets should find considerable application in industry. Their low cost could drive the widespread reconstitution, and thereby, recovery of coal fines resulting in both economic and resource recovery benefits.

ADVANCED TECHNOLOGY FOR THE RECOVERY, STORAGE, AND UTILIZATION OF NATURAL GAS

13

Application of Exploration and Advanced Well Completion Technology to High Productivity Coalbed Methane Fairways--Advanced Resources International, Inc., 165 South Union Boulevard, Suite 816, Lakewood, CO 80228; (303) 986-2121
Mr. A. David Decker, Principal Investigator
Mr. Vello A. Kuuskraa, Business Official
DOE Grant No. DE-FG03-93ER81502
Amount: $599,832

The growth of coalbed methane has been dramatic and highly valuable to the gas and oil industry. Looking across all of coalbed methane production, one quickly grasps a startling observation -- the majority of U.S. coalbed methane production, 1.2 billion cubic feet per day out of 2 billion cubic feet per day, is provided by less than 10% of the producing wells, the highly prolific open-hole cavity wells located in the San Juan basin cavity fairway. Finding and efficiently developing other coalbed methane fairway is the top priority for a healthy, growing coalbed methane industry. During Phase I, the controlling parameters for highly productive cavity completions and the set of geologic processes responsible for these favorable reservoir properties were documented. An exploration rationale and a set of geological/geophysical tools were set forth to "rediscover" the San Juan basin "cavity fairway". Using this exploration strategy in conjunction with exploration tools, the San Juan basin was specifically high graded with a final partition that accurately defined the fairway location and outlined an area within which 80% of the wells produce at a rate of 1 million cubic feet per day or greater. Using the same exploration strategy, a preliminary geologic evaluation suggests that cavity-type fairways are likely to exist in other North American coal basins. In Phase II, the two basins most suitable for cavity well completions will be screened. The Phase I exploration strategy will be used to identify the cavity fairways in these basins and to locate specific drilling sites. The wells will be tested and then cavitated to determine the economic feasibility of cavitation in these new basins.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project should demonstrate that coalbed methane production economics can be substantially improved by the utilization of the cavity completions in coal basins where this technique has not been attempted. Widespread utilization of the technology should be a natural outgrowth when the economic benefit has been demonstrated in Phase II.

14

A Novel Process for the Removal of Nitrogen from Nitrogen-Containing Natural Gas: Development of Water-Based Absorbents--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. David K. Lyon, Principal Investigator
Dr. Walter C. Babcock, Business Official
DOE Grant No. DE-FG03-93ER81551
Amount: $600,000

Domestic natural gas provides an increasingly important portion of the U.S. energy supply. Estimated U.S. gas reserves are about 1000 trillion standard cubic feet (SCF), or about 1000 quads. About 25% of the estimated reserves are contaminated with nitrogen (N_2) to the extent that the gas cannot be used without N_2 removal. No technology exists today for the cost-effective removal of N_2 from natural gas at the wellhead while keeping gas losses during treatment below a 3% limit imposed by environmental and economic constraints. Over the past three years, a process has been developed for purifying N_2-contaminated natural gas at the wellhead. In this process, the N_2 is separated from the rest of the natural gas using a regenerable absorbent based on aqueous solutions of transition-metal complexes. The final N_2 absorbent ideally will have the following characteristics: 1) rapid absorption of nitrogen at the pressure and temperature of the natural gas feed stream (high pressure and ambient temperature), 2) rapid desorption of nitrogen under mild conditions (ambient pressure and moderate temperature), 3) extremely high selectivity for nitrogen over methane, and 4) appropriate kinetics and lifetime properties. During Phase I the understanding of the relationship between the molecular structure of the N_2-binding compounds and their properties was advanced, and the performance of candidate N_2 absorbents was substantially increased. Specifically, the feasibility of identifying new absorbents with solubilities and N_2-binding capabilities that met Phase I targets was demonstrated. A computer model was developed that predicted process economics at the current level of performance of $0.55/MSCF, based on reasonable absorbent cost and lifetime assumptions. This level of performance would enable economical treatment of a small percentage of the N_2-contaminated U.S. gas reserves, and this progress sets the stage for continued collaborative funding from a commercialization partner and for an accelerated Phase II project. The goal of this project is to prepare new N_2 absorbents (based on Phase I results) that exhibit superior N_2-binding properties and that, when their production is scaled up, can lead to process costs approaching the target of $0.25/MSCF. This level of performance would allow for economical treatment of virtually all known N_2-contaminated U.S. gas reserves.

Anticipated Results/Potential Commercial Applications as described by the awardee: An economical process for purifying N_2-contaminated natural gas should render up to 250 trillion SCF (250 quads) of low-grade natural gas saleable. This gas, at today's prices, is valued at $(7 to 8) billion each year over a 50-year period. In addition, this project should serve as the groundwork for development of other liquid-absorbent-based separation processes, such as separation of olefins from paraffins, and fractionation of olefin isomers.

15

A Pressure Swing Adsorption Process for Nitrogen Rejection from Natural Gas--Northwest Fuel Development, Inc., 4064 Orchard Drive, Lake Oswego, OR 97035; (503) 699-9836
Dr. Peet M. Soot, Principal Investigator
Dr. Peet M. Soot, Business Official
DOE Grant No. DE-FG03-93ER81552
Amount: $600,000

The technical and economic feasibility of the pressure swing adsorption (PSA) process was demonstrated in Phase I. The laboratory work showed that activated carbons (AC) affect the desired separation between methane and nitrogen. Some commercially available ACs were shown to have a selectivity of methane to nitrogen of three or more. A kinetics test showed that these materials adsorb methane very rapidly, a major unexpected positive result. Because the PSA process can be cycled so quickly, the AC adsorbents are much better than more expensive carbon molecular sieve materials (CMS) used by other developers. Based on lab test results and on mathematical modeling, a conceptual PSA process was developed and a preliminary demonstration plant was designed. The plant is expected to produce pipeline quality methane gas (exceeding 97% methane) from a feed stream containing only 83% methane. The plant recovers 57% of the feed methane. Some of the unrecovered methane is used as fuel for the necessary compressors, and the balance is reinjected into the producing formation at some distance from the producing well. The demonstration plant, planned for Phase II, could process 300 MCFD (thousands of cubic feet per day) of feed gas. This should yield 149 MCFD of product gas at a cost of $1.40 per MCF. Even this small plant should produce an economically competitive product since present day natural gas prices at the wellhead are generally in excess of $2.00 per MCF. A larger plant, capable of producing 1 MMCFD of pipeline gas, should have a processing cost of only $0.70-1.00/MCF. The Phase II process demonstration unit (PDU) should provide the foundation for rapid commercial deployment of this technology in Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: The Nation has nearly 250 trillion cubic feet (TCF) of sub-quality natural gas. Successful development of this process should provide economic, national security, and environmental benefits. Cost estimates show that this process could provide gas at lower prices than current levels. It uses a domestic resource - not an imported one. Environmental benefits arise from the capture of greenhouse gas: methane.

COAL-BASED POWER SYSTEMS TECHNOLOGY

16

A Carbonate Fuel Cell Monolith for Low-Cost and High Power Density Operation--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 792-1460
Mr. Randolph Bernard, Principal Investigator
Dr. Hans Maru, Business Official
DOE Grant No. DE-FG05-93ER81510
Amount: $599,993

Present generation carbonate system designs are attractive for utility application because of high efficiency, competitive cost of electricity, and superior environmental performance. The carbonate fuel cell subsystem, however, represents about 30% of the power plant system cost and requires replacement every five years or so, contributing to higher operations and maintenance cost. Significant cost reduction of this major system component should make this power plant significantly less expensive and therefore more appealing for wider market penetration. Phase I verified the proof-of-concept of a second generation monolithic carbonate fuel cell design, which provides cost reduction via higher power density operation and lower material usage. The basic monolithic cell design was manufactured using simple industrially practiced processes. Reduced cell height, enhanced cell active area, and reduced cell resistance resulted in an approximately 100% improvement in volumetric specific power density while using 58% less material over the baseline design. Phase II will further optimize cell designs, demonstrate endurance, and scaleup this technology from the labscale single cell level to the large area multicell stack level. Phase II will culminate in a 6-cell (6,000 cm^2) stack test for approximately 1000 hours to characterize startup, performance, thermal management, and pressure drop aspects of the proposed concept. Following the experimental verification, commercial-scale stack design will be recommended for further testing and implementation in Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: A significant capital (as well as operation and maintenance) cost reductions of the carbonate fuel cell power plant over the conventional design are anticipated. This should have a major impact on commercialization of the carbonate power plant. It is expected that developments under this project should be rapidly scaled up to 2MW power levels because of the obvious advantages to the electric utility community. Additional applications for these cheaper power systems include ship propulsion and industrial co-generation uses.

17

Advanced Ceramic Fibers for a Carbonate Fuel Cell Matrix--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 792-1460
Dr. Chao-Yi Yuh, Principal Investigator
Dr. Hans Maru, Business Official
DOE Grant No. DE-FG05-93ER81512
Amount: $599,950

Thermo-mechanical stresses, particularly from the cooldown-restart cycle (thermal cycling) of a power plant, have an adverse effect on the carbonate fuel cell matrix. Thermal cycling impacts matrix gas sealing efficiency, carbonate fuel cell useful life, conversion efficiency, and the decay rate. The overall goal of this project is to improve the strength and thermal cyclability of the carbonate fuel cell matrix by reinforcing it with strong, as well as stable, ceramic materials. In Phase I, manufacturability of stable, secondary ceramic materials, using innovative manufacturing methods, was successfully demonstrated, and a five-fold improvement in thermal cyclability of a reinforced matrix (not with stabilized ceramic material) was attained in a single-cell test. Building on these successes, Phase II will focus on: 1)optimization of the manufacturing method(s) of the stable ceramic materials and the strengthened matrix and 2) single-cell evaluation. Phase II will culminate in a full-area (8000 cm^2) stack test to demonstrate the readiness of the strengthened matrix for use in commercial stacks. The anticipated Phase III effort will focus on setting up a manufacturing line for volume production.

Anticipated Results / Potential Commercial Applications as described by the awardee: The objective of this SBIR research is to develop strong ceramic reinforcement materials that can improve matrix thermal cycling strength. Improvement of system performance, as promised by the robust matrix, is expected to significantly increase the competitive position of this unique product. The materials could be used in commercial stacks for long-life high-efficiency fuel cell power plant application. The research should lead to a speedy commercialization of carbonate fuel cell technology. The developed strong ceramic materials should also be very useful for reinforcing other types of advanced composites.

18

Demonstration of an Integrated Carbon Dioxide/Thermal Management System for Carbonate Fuel Cells--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 792-1460
Mr. Randolph Bernard, Principal Investigator
Dr. Hans Maru, Business Official
DOE Grant No. DE-FG05-93ER81511
Amount: $599,968

During Phase II, tests will be conducted on an advanced carbon dioxide/thermal integration concept for carbonate fuel cells in a thermally representative multicell stack. Present generation carbonate system design is attractive for utility applications because of high efficiency, competitive cost of electricity, and superior environmental performance. However, further simplifications are possible to reduce its footprint, eliminate some subsystem components, and thereby reduce overall system cost by as much as $150/kW. In carbonate fuel cells, carbon dioxide generated on the fuel side is transferred to the oxidant side via a fuel exhaust burner. The burner is also utilized to preheat the incoming air to about 1100°F. In a conventional system configuration, this CO_2 transfer/thermal management subsystem requires a special burner and significant piping network. In this project, research will be conducted to eliminate the burner and associated piping in its entirety and integrate the function in the stack design itself. This concept has been successfully tested in Phase I at a laboratory-scale single cell level. The feasibility of direct transfer of fuel exhaust to the oxidant side without requiring any burner was demonstrated for over 4000 hours. An initial verification was also performed in an operating subscale multicell stack. In Phase II, the concept will be tested in a thermally self-sustaining multicell stack built with full size cell components. An 18-cell (6 ft^2 area) stack will be developed and tested for approximately 2000 hours to characterize resulting temperature gradients and to understand and resolve cell design, startup, and pressure drop issues associated with the concept.

Anticipated Results / Potential Commercial Applications as described by the awardee: A reduction in capital cost of \$150/kW over the conventional design is anticipated. This is a significant cost saving and simplification in addition to reduced footprint and heat losses, and therefore is expected to be a very attractive power plant design. It is expected that Phase II developments in this project should be rapidly scaled up to 2 MW power levels because of the obvious advantages to the electric utility community. Another application for these lighter weight and more compact power systems is ship propulsion. This is an application in which there is growing interest because of air quality regulations.

ADVANCED FOSSIL RESOURCE UTILIZATION

19

Use of Supervisory Control Techniques for Optimization of Environmental Emissions in Power Plants--Praxis Engineers, Inc., 852 North Hillview Drive, Milpitas, CA 95035; (408) 945-4282
Ms. Suzanne Shea, Principal Investigator
Mr. Randhir Sehgal, Business Official
DOE Grant No. DE-FG03-93ER81495
Amount: \$599,444

The Supervisory Optimization Control System (SOCS) is a software package for on-line use in fossil-fired power plants. It will be developed using the advanced simulation and control techniques of Artificial Neural Systems and Fuzzy Logic Control. Its major attribute is that under any given set of environmental emission constraints, i.e., NO_x and SO_2 limits, it can provide the plant operator with recommendations on all major operator-controllable setpoints such that the resulting cost of electricity is minimized. Phase I examined three modeling and computational techniques including analytical and empirical models, artificial neural systems, and fuzzy logic control to determine their suitability for the development of SOCS. Each of these techniques has the potential of working by itself. However, each also has major weaknesses which reduce its effectiveness or increase system costs. Analytical models can become too complex; artificial neural systems, while capable of easily modeling nonlinear processes, will not have access to real-world optimal performance data to train them effectively; and fuzzy logic controllers, while able to find least-cost solutions from a base of easily formed rules, will require rapid feedback from the process itself over a number of iterations to arrive at the optimum mix of setpoints. The selected design of SOCS overcomes these difficulties by combining the strengths of each technique while not using them in areas where they are weak. The planned design will use analytical modeling only for the linear components where their application is straightforward and direct. Artificial neural systems will be used in modeling those parts of the process which are inherently nonlinear and where the chemistry is not fully understood. These modeling techniques will be combined with the ability of the fuzzy logic controller to arrive at the optima by using a simple and intuitive rule-based understanding of boiler operations and cost structures. The resulting product will be able to model power plant performance from existing data logs and will require only minimal plant testing to configure it for each plant. It should be inexpensive to customize, and its interface will be designed so that operators can use it without much training.

Anticipated Results / Potential Commercial Applications as described by the awardee: The result of this project will be a software product able to optimize the environmental and economic aspects of power plant operations on-line. Power plants burning coal, oil, or gas should be the primary market for SOCS. However, because of its ability to optimize any process, the product should find a much wider market covering many industries. Potentially, a large market for the off-line version of SOCS also exists. Plant engineers, research workers, and design engineers should find it a valuable tool for exploring options and evaluating ideas.

CHEMICAL PRODUCTS FROM BIOMASS

20

Production of Carbon Materials from Lignin--Advanced Fuel Research, Inc., 87 Church Street, East Hartford, CT 06108; (203) 528-9806
Dr. Chad M. Nelson, Principal Investigator
Dr. Peter R. Solomon, Business Official
DOE Grant No. DE-FG05-93ER81593
Amount: $599,988

While the chemical uses of lignin-derived products have been much studied, the material uses have a larger potential for production of high value products and have received relatively little attention. Carbon materials, especially carbon fibers, are among the highest value products which can be produced from lignin. Consequently, processes which can utilize lignins for carbon fibers or other high value carbon materials (e.g., carbon-carbon composites, battery or fuel cell electrodes, specialty activated carbons for gas storage, catalysts) have the potential for a high payoff. The ability to form carbon fibers and several other graphitic carbon materials (e.g., graphite, coke, electrodes) depends on the development of a liquid crystal system called mesophase. The Phase I project demonstrated that hydrothermal treatment of lignin allows for selective removal of the reactive oxygen functional groups which normally prevent extensive mesophase formation. A high mesophase content was thus demonstrated for a lignin derived material, making lignin a suitable precursor for a range of carbon materials applications. Phase II will build on the success of Phase I to: 1) optimize the hydrothermal and thermal treatment steps; 2) develop a quantitative model of the steps; 3) design, construct and operate a bench scale unit to produce mesophase (or isotropic) pitch from lignin; 4) evaluate the products; 5) design a pilot scale unit for Phase II; and 6) conduct a market assessment for the optimal use of the products.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful completion of this project through Phase III should result in a process to convert low value, technical lignins to high value carbon materials. The results would also include a quantitative model which relates the lignin derived pitch composition to the process conditions, and the further development of on-line diagnostics for process control. These results should increase the utilization of lignin to replace fossil fuel derived feedstocks and should identify applications where the unique properties of lignin result in a superior product. It should also result in the utilization of lignin as a raw material for high technology, internationally competitive industries.

BIOMASS ELECTRIC POWER TECHNOLOGY

21

A Novel Hot Gas Cleanup System for Biomass Power Technology--LSR Technologies, Inc., 898 Main Street, Acton, MA 01720; (508) 635-0123
Dr. Leo A. Smolensky, Principal Investigator
Mr. S. Ronald Wysk, Business Official
DOE Grant No. DE-FG02-93ER81613
Amount: $600,000

Several unit operations are involved in the production of electricity from biomass waste fuel via gasification. Hot gas cleanup continues to be a critical unit operation because particulate and alkali removal are essential to protect the downstream combustion turbine. A high temperature Core Separator has been developed and tested in Phase I as a hot gas cleanup device. It has shown high retention of particles 3 micrometers in diameter (and above) at temperatures of 540 degrees Celsius (1000 degrees Fahrenheit). The particle removal efficiency obtained in these tests can meet the stringent requirements of aeroderivative turbines, as used in biomass power generating systems. Phase I results have clearly demonstrated proof-of-concept under simulant conditions. This project will now shift to pilot-scale testing of a gasifier firing biomass waste fuel. The work will be performed in collaboration with a developer of advanced biomass technology and will culminate in a series of high temperature tests for particulate/alkali removal in a 15-ton-per-day process development unit.

Anticipated Results / Potential Commercial Applications as described by the awardee: Gasification of wood waste is being actively developed for the paper and wood industry. There is an immediate need for improved particulate control technologies for both atmospheric and pressurized systems. Upon completion of this Phase II project, the Core Separator can be applied to those systems.

ADVANCED WINDOW AND GLAZING TECHNOLOGIES

22

Flexible Electrochromic Window Materials Based on Poly(diphenylamine) and Related Conducting Polymers--Ashwin-Ushas Corporation, Inc., 206 Ticonderoga Boulevard, Freehold, NJ 07728; (908) 462-1270
Dr. P. Chandrasekhar, Principal Investigator
Dr. P. Chandrasekhar, Business Official
DOE Grant No. DE-FG05-93ER81631
Amount: $599,893

The present project seeks to further develop to a level of commercial marketability a novel electrochromics technology based on the conducting polymers (CPs) Poly(diphenylbenzidine) (P(DPBz)) and Poly(diphenylamine) (P(DPA)). Compared to other CPs and extant technologies such as metal oxides, this technology offers the advantages of glass clear transparency, broad band (500-900 nm and into IR) adsorption, high color contrast, extended cyclability in air, good open circuit memory, and potentially lower cost. The objective is for a possible retrofit rather than replacement application. In Phase I, hermetically sealed, small-area devices were demonstrated with 8% optical degradation over 40,000 cycles, color contrast of 70%, and extended shelf lives. The design included both flexible and rigid devices, and incorporated novel sealing and polymer deposition methods. In Phase II, sealed large-area devices (900 cm^2 and larger stacks) will be fabricated using adaptations of the coating and sealing methods developed in Phase I and tested optically for electrochromic performance. These devices will incorporate autocalibration, control of spiking, continuous color control and other optimizing features. Detailed cost estimates will be determined for Phase III development. The retrofit, as well as original equipment, will be demonstrated at various size levels.

Anticipated Results / Potential Commercial Applications as described by the awardee: Extant technologies, primarily electrochromic metal oxides, have had drawbacks of costs, stability, dynamic range, and (color contrast which have prevented their commercial implementation. The present technology is in some ways a radical departure from traditional electrochromics, and offers very high color contrast, high cyclability/stability, long shelf life, and amenability to large-area manufacture. It should be applicable to both original-equipment and retrofit modes, the latter entailing high cost savings. It thus has potential to supersede extant technologies.

23

Advanced Window Materials Based on Conducting Polymer/Sol-Gel Ceramic Composites and Tungsten Oxide Coatings--Gumbs Associates, Inc., 11 Harts Lane, East Brunswick, NJ 08816; (908) 257-9049
Dr. Guang-Way Jang, Principal Investigator
Dr. Ronald W. Gumbs, Business Official
DOE Grant No. DE-FG05-93ER81632
Amount: $600,000

The objective of Phase II is to design and fabricate large-area durable electrochromic windows for energy-conserving applications such as day lighting and thermal control. It was successfully demonstrated that composites of conducting polymer and hybrid sol-gel material adhere strongly on the indium-doped tin oxide (ITO) surface and provide superior optical properties for fabrication of large-area electrochromic devices. The development of a soluble polyaniline allowed the fabrication of a 30 cm X 30 cm (1 sq. ft) polyaniline/sol-gel based electrochromic device which switched between transparent and green. A sol-gel processing technique was developed for fabricating tungsten oxide (WO_3) coatings to be used as a complementary electrode for improving durability and spectra response of the electrochromic devices. In Phase II, additional processible conducting polymers will be optimized, the sol-gel technique will be refined for the fabrication of WO_3 coatings, the electrochromic layers will be spray-coated on ITO polyester for fabrication of electrochromic devices, and large-area (>1 sq. ft) electrochromic devices will be demonstrated and tested.

Anticipated Results / Potential Commercial Applications as described by the awardee: The results of these investigations should be directly applicable to many key windowing devices currently in use and should meet the future challenges of optical material design. The commercial applications of conducting polymer/sol-gel composites should include: electrochromic devices, anticorrosion coatings, conductive adhesives, biosensors, and rechargeable batteries.

24

Novel Spectrally Selective Window Films Based on Multiplexed Holography--Physical Optics Corporation, 2545 West 237th Street, Suite B, Torrance, CA 90505; (310) 320-3088
Dr. Gajendra Savant, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-93ER81582
Amount: $599,999

In response to the need for energy saving glazing structures, passive Multiplex Holographic Films (MHF) were developed in Phase I to provide efficient daylighting and solar heat control in both the Infrared (IR) and Ultraviolet (UV) spectral regions. These films are based on volume holography and utilize non-imaging beam shaping and nonlinear effects in holographic materials. In particular, Phase I showed that: transmission type holographic structures can provide non-imaging beam shaping with diffraction efficiencies up to 90%; non-linear properties of certain holographic materials can be used to produce fundamental, higher harmonic Lippman gratings with efficiencies in excess of 95% in a single holographic recording; and broadband spectrally selective holographic mirrors, exhibiting high reflectivity in the IR and UV regions and high transmission in the entire visible spectral range, can be produced. In Phase II, large scale, low cost MHF films will be produced that can be readily integrated into current glass/window production processes, as well as retrofitted to existing windows. The goal is to develop an energy efficient MHF structure that will be mass-producible and highly competitive with state-of-the-art technologies in terms of both performance and cost. This structure should be capable of providing four key functions: daylighting, uniform distribution of visible solar light, heat control, and UV rejection.

Anticipated Results/Potential Commercial Applications as described by the awardee: MHFs should provide net energy savings in most areas of the United States. Additional benefits should include: high efficiency for both daylighting and IR/UV reflection, scalability to current residential and commercial window sizes, cost effectiveness, durability for long term use without deterioration, retrofittability to already installed windows, or capability to be laminated during the manufacturing process. The installation of MHFs should lead to substantial savings within a few years of their application, while simultaneously reducing environmental pollution.

25

Feasibility of Using Squeeze Roll Coating to Form Sol-Gel Derived Layers for Switchable Electrochromic Windows--SAGE Corporation, P.O. Box 278, Brett and Bowser Road, Piscataway, NJ 08855; (908) 932-3300
Dr. Frank B. Ellis, Jr., Principal Investigator
Mr. John E. Van Dine, Business Official
DOE Grant No. DE-FG05-93ER81545
Amount: $600,000

Switchable electrochromic (EC) glazings have potential use in a vast number of energy-saving smart window applications. For EC smart windows to achieve full commercial potential, manufacturing technology must be developed that can cost-effectively produce large-area, functional EC films uniformly. Previously, an all-ceramic, thin-film EC device was developed that combines durable materials and device structure with cost-effective manufacturing techniques. An innovative "roll-gel" approach, potentially useful for three EC layers, combines novel sol-gel film chemistry with the adaptation of a high-throughput web coating process. Phase I provided confirmation of the initial technical feasibility of using this roll-gel coating process for depositing a tungsten oxide (WO_3) electrochromic electrode (ECE) layer on glass. With three different stabilized, non-aqueous precursor solutions and a standard dip coating procedure, 180 nm WO_3 films (6 dips required) were made. Except for a slight bleached-state transmission loss, EC devices with dip coated WO_3 films compared well to those with sputtered WO_3. Modified solution composition, synthesis, and post-coating treatment procedures should remedy this loss. Also developed was a thickness/color chart to correlate observed film color with thickness and uniformity. In this project, a 24 inch roll-gel coating system will be specified and procured, and the coatings will be parametrically developed so that a well-characterized, statistically-proven, manufacturing process exists for depositing the ion conductor (IC), the ECE and, possibly, the counter electrode (CE) layers. The work plan is defined in 3 parts: 1) perform more engineering studies to complete the roll-gel system specifications for the desired film thicknesses, 2) work with a qualified equipment supplier to design and build a 24 inch wide roll-gel coating system equipped with glass transport and curing capabilities, and 3) fabricate functional 10 inch by 12 inch EC devices with optimized roll-gel coated films and quantify projected manufacturing costs.

Anticipated Results/Potential Commercial Applications as described by the awardee: If successful, the Phase II should provide the needed manufacturing technology and economics to produce commercially viable EC smart windows through the development of a cost-effective roll-gel coating system. While the focus will be on specific opportunities associated with architectural glass markets (residential and commercial), EC smart windows have the potential to spawn a wide range of advanced applications and new opportunities in architectural, transportation, and specialty optical control markets.

EDUCATIONAL TECHNOLOGIES

26

A Laboratory/Field Workstation for Science Education--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112; (303) 792-5615
Dr. Judith A. Armstrong, Principal Investigator
Dr. Judith A. Armstrong, Business Official
DOE Grant No. DE-FG02-93ER81585
Amount: $600,000

Improvements in math and science education, while maintaining reasonable school budgets, may be achieved by introducing a low-cost system which brings state-of-the-art technology into the high school laboratory. A laboratory/field workstation will take state-of-the-art tools available for researchers and integrate them into a cost-effective, easy-to-use, modular system for high school laboratories. Proof-of-concept hardware and software, along with curriculum planning and field testing, were developed during Phase I. The hardware consists of a hand-held, field-portable, data-acquisition unit with a set of sensor modules (measurement devices for temperature, pressure, pH, etc.). This hardware, along with software for downloading to a desktop computer, was successfully field tested in both middle and high schools. Curriculum planning, also performed during Phase I, led directly to a relationship with several educational organizations that will be involved in Phase II. The objective is to commercialize an inexpensive system to enhance science education at the high school level through the use of hands-on experimentation. In Phase II, the hardware will be improved and educational software and curricular materials will be added to create an educational system based on "hands-free" science.

This prototype system, including hardware, software, and curricular units, will be field tested in the major science areas in several high schools for a year and a half during Phase II.

Anticipated Results / Potential Commercial Applications as described by the awardee: The system should improve science education through the use of "hands-on" experimentation. The potential market includes all branches of high school science education. Phase III refinements should expand the market into middle schools and colleges.

27

Living On Earth: A Multimedia-Based Learning Environment for the Earth Sciences--
Videodiscovery, Inc., 1700 Westlake Avenue North, Suite 600, Seattle, WA 98109; (206) 285-5400
Dr. D. Joseph Clark, Principal Investigator
Mr. Douglas C. Orkney, Business Official
DOE Grant No. DE-FG03-93ER81651
Amount: $600,000

Living on Earth, a multimedia-based learning environment for 8-12th grade earth science education, will be created on CD-ROM and videodisc. The system will consist of a visual database delivered in both analog and digital formats, detailed lesson plans, and textural support materials. The system will permit the integration of new thematic, interdisciplinary approaches to earth science teaching into existing classrooms. In Phase I, a production system was produced that permits multi-platform development of content in print, Level I videodisc (videodisc player operated without a computer), Level III videodisc (videodisc player operated with computer software), and CD-ROM. A prototype geology videodisc and CD-ROM were developed, and four earth science lessons at the junior high and high school levels were tested. In Phase II, a comprehensive multimedia collection to augment the geology videodisc and CD-ROM will be completed. The remaining subject areas include astronomy, oceanography and meteorology.

Anticipated Results / Potential Commercial Applications as described by the awardee: The product will be distributed to secondary schools nationwide. The comprehensive visual database and accompanying print lessons can be customized to local curricular needs to improve the teaching of earth and space science. Wide utilization of the product should facilitate the shift to an interdisciplinary, application-oriented approach. Additional software products that are correlated to the *Living on Earth* multimedia product could be developed by third party vendors.

INSTRUMENTATION FOR OCEAN MEASUREMENTS

28

An Oceanographic Carbon Dioxide (CO_2) Sensor--
Umpqua Research Company, P.O. Box 791, Myrtle Creek, OR 97457; (503) 863-7770
Dr. James R. Akse, Principal Investigator
Mr. John S. Aker, Business Official
DOE Grant No. DE-FG03-93ER81641
Amount: $600,000

Phase I demonstrated the feasibility of a novel atmospheric/oceanic CO_2 analyzer using membrane transport, chemical amplification, and specific conductance detection. The innovation offers several distinct advantages over conventional gas chromatographic and infrared spectrometric methods of analysis including simplicity, reliability and robustness of detector components, stability, low cost, small size, modest power requirements, ease of automation, and capability for unattended operation with a high potential for in situ recalibration. Although initially targeted to the determination of atmospheric CO_2 pressure, Phase I clearly showed that the new monitoring technology is applicable in sea water. At typical oceanic dissolved inorganic carbon levels of ~350 microatmospheres, the analyzer has determined CO_2 pressure with a precision of ± 5 microatmospheres. In Phase II an automated, accurate, robust, and simple prototype device for the determination of CO_2 pressure to ± 1-2 microatmospheres in sea water will be developed.

In particular: membrane characteristics, contractor design, CO_2 sorbent solution composition, and analyzer configuration will be optimized; environmental factors which influence analyzer performance will be quantified and compensation algorithms will be developed; a method of in situ calibration will be developed to extend the duration of untended operation; controlled release of biocides will be investigated for biofouling mitigation; statistical data will be generated to verify long term analyzer performance against standard sea water solutions; the prototype device will be constructed to permit automated operation; and laboratory and field tests up to 30 days will be conducted to demonstrate analyzer performance on both standard and real sea water with untended operation. A final report will describe the prototype development, design, fabrication, operational procedures, and performance characteristics along with a presentation and analysis of pertinent performance data.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that three commercial products should stem from the Phase II development of this technology: a moderately expensive and highly accurate CO_2 monitoring system for the most demanding research oceanographic applications, a less expensive and reasonably accurate system for widespread buoy deployment in support of global oceanic and atmospheric CO_2 mapping efforts, and an inexpensive and moderately accurate CO_2 sensor for greenhouses. An improved detector for very sensitive (ppb) Total Inorganic/Organic Carbon Analyzers which are based on conductivity detection of CO_2 may also originate from this work.

DESIGN AND APPLICATIONS OF NOVEL MATERIALS

29

Porous Aluminum Nitride Part Fabrication to Support Advanced Battery Development--
Advanced Refractory Technologies, Inc., 699 Hertel Avenue, Buffalo, NY 14207; (716) 875-4091
Mr. Thomas J. Mroz, Principal Investigator
Mr. Keith A. Blakely, Business Official
DOE Grant No. DE-FG05-93ER81637
Amount: $599,703

In Phase I, sintered porous Aluminum Nitride (A1N) materials were shown to be suitable for separators in lithium-metal sulfide batteries. The sintered separator improves the structural integrity of the battery and allows reduction of the cell size. However, the current cost of A1N separators is more than the currently used Magnesium Oxide (MgO) powder materials. Methods of decreasing the cost of A1N separators have been identified - they involve reduction in powder cost, improvements in tape processing methods, and utilization of continuous firing methods. This project will investigate methods of obtaining these cost reductions through processing improvements. Additionally, extended battery testing will be performed to assist in separator plate optimization and to develop baseline characteristics for baseline development. Opportunities within the process have been identified that will provide suitable cost savings which would result in a cost competitive separator concept. Battery fabricators identified in Phase I will be used to evaluate these A1N separators in preparation for commercialization of the concept in Phase III. Other non-battery opportunities for the porous A1N structure have been identified which provide additional avenues for product commercialization.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase II is intended to provide a sintered A1N product technically and economically suited for lithium metal sulfide batteries. Additionally, these materials will be of interest for new high thermal conductivity composites. Commercial applications include electric vehicles and commercial devices for batteries, and substrates and packages for composites.

30

Oxide Dispersion Strengthened Silver for Use in High-Temperature Superconductor Composite Wires--American Superconductor Corporation, 2 Technology Drive, Westborough, MA 01581; (508) 836-4200
Dr. Gilbert N. Riley Jr., Principal Investigator
Mr. Edward P. Hamilton, Business Official
DOE Grant No. DE-FG02-93ER81605
Amount: $600,000

The strengthening of high-temperature superconductor (HTS) composite conductors with oxygen dispersion strengthened (ODS) silver is planned. State-of-the-art HTS composite conductors consist of ceramic superconductor filaments encased in a silver (Ag) sheath. For reasons of chemical compatibility and oxygen permeability, silver is the only material that can be used to sheathe HTS. However, the current method of manufacture weakens the silver sheath, resulting in reduced HTS conductor strengths. The low strength of these composite conductors is a major obstacle in the development of HTS wires for applications requiring robust conductors such as power transmission cables, SMES, and motors. ODS increases the strength of the sheath, while maintaining chemical compatibility and oxygen permeability of silver. In Phase I, two ODS-Ag systems and a method of fabrication were identified that provide the necessary thermomechanical stability and strength. In Phase II, the ODS-Ag materials will be integrated with HTS in composite form. Specific process issues unique to the materials and methods identified in Phase I will be addressed. Using insights gained from process-property-microstructure relationships and statistically designed experimental techniques, novel processes that simultaneously optimize the performance of the ODS-Ag sheath and the HTS will be developed. The resulting technology will be scaled up so that long lengths (~1km) of high-strength and high-performance HTS composite conductor can be manufactured on a routine basis.

Anticipated Results / Potential Commercial Applications as described by the awardee: The strengthening of HTS composite wires should accelerate commercialization and broaden the commercial impact of HTS. In addition, an increased sheath resistance should reduce AC losses. Specific applications that should benefit from high-strength, low loss HTS conductors include: power transmission cables, motors, generators, SMES and transformers. The commercialization of HTS could result in significant energy savings and the development of new technologies.

31

Capacitive Energy Storage Using High Surface Area Hafnium Compounds--Chemat Technology, Inc., 19365 Business Center Drive, Suite 8, Northridge, CA 91324; (818) 727-9786
Mr. Haixing Zheng, Principal Investigator
Dr. Su-Jen Ting, Business Official
DOE Grant No. DE-FG03-93ER81570
Amount: $600,000

High surface area materials have diverse applications, such as for energy storage systems and for catalytic converters. In Phase I, the feasibility of fabricating transition metal compounds with high surface area and high double layer capacitance using the sol-gel process was demonstrated, and a supercapacitor cell was prepared. Several approaches were tried in preparing carbides, nitride, and borides of high surface area with the focus on hafnium compounds which have the highest capacitance, $>200\ \mu F/cm^2$. Hafnium carbonitrides with surface area up to 123 m^2/g were fabricated, and the supercapacitor cell was constructed using these porous hafnium carbonitrides. The cell has an energy density of 6.4 J/g which is close to the 10 J/g energy density of ruthenium dioxide (RuO_2). In Phase II, energy storage capabilities will be enhanced by increasing the surface area of hafnium carbonitride and tailoring the chemistry of the pore surface. The best processing variables for fabricating capacitive energy storage cells will be identified. The optimized cells will be tested for various properties: operation temperature, working voltage, capacitance, equivalence series resistance, and leakage current. All technical parameters will be measured and a technical database on these supercapacitors will be prepared for future commercialization of the supercapacitors. The process will be scaled up to pilot plant stage, and the production cost will be estimated.

Anticipated Results / Potential Commercial Applications as described by the awardee: The technology should have application in many situations where batteries are now used, especially for high pulse power.

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Low Temperature Deposition of Titanium Nitride--ISM Technologies, Inc., 9965 Carroll Canyon Road, San Diego, CA 92131; (619) 530-2332
Dr. Anthony J. Perry, Principal Investigator
Mr. Robert J. Stinner, Business Official
DOE Grant No. DE-FG03-93ER81577
Amount: $599,677

Titanium Nitride (TiN) has been found to be an excellent coating for wear resistant applications. However, the deposition temperature of about 450°C is far too high for many applications of machine component parts made from alloy steels or aluminum alloys, where deposition temperatures over 150°C would deleteriously affect the mechanical properties of these substrates. When TiN coatings are deposited at such a low temperature, using current conventional industrial technologies, the micro-structure is not dense and the resulting coatings have mechanical properties far inferior to those made at the higher temperatures. Phase I demonstrated that hard, well-adhering TiN with low residual stress and a dense micro-structure can indeed be made at 150°C (by reactive deposition from a cathodic arc evaporation source), using the Hyper-Ion process developed by ISM Technologies. In the hyper-ion process, a pulsed high voltage bias is applied to the work-piece which produces a marked improvement in properties. In Phase II, the deposition process will be further developed and refined to produce a well-defined coating process, which can be scaled up into production and is aimed at providing optimized wear resistance industrial parts.

Anticipated Results / Potential Commercial Applications as described by the awardee: This Phase II project should demonstrate that titanium nitride hard coatings deposited at 150°C by a hyper-ion process are capable of significantly reducing the wear of automotive and other components for which deposition at higher temperatures is not suitable. Potential commercial applications should include piston rings, valve stems, pistons, fuel injector plungers, and injection molds.

33

Coated Micrograin Carbides for Wear Resistance--Ultramet, 12173 Montague Street, Pacoima CA 91331; (818) 899-0236
Mr. Andrew J. Sherman, Principal Investigator
Mr. Craig N. Ward, Business Official
DOE Grant No. DE-FG03-93ER81584
Amount: $599,557

Micrograin carbides are small grain size (1-5 μm diameter) particles of tungsten carbide (WC) that have been "cemented" together with a predominantly cobalt matrix by liquid-phase sintering. The result is an excellent material for carbide cutting tools and other wear- and/or corrosion-resistant parts, because their finer grain size yields better mechanical properties than typical carbide tools (with grain sizes 20-50 μm). Some of their potential advantage is negated, however, by the difficulty of handling such fine powders and mixing them with cobalt powders to form the blend which is then preformed and sintered. Problems arising during handling and blending include increased impurity content, nonhomogeneous distribution of matrix powders, and WC-WC particle contact, all of which lower mechanical properties in the finished part. Also, substantial grain growth occurs during the liquid-phase sintering step. The result is that cobalt content must be increased to achieve the desired fracture toughness and transverse rupture strength, with a corresponding decrease in tool hardness and life and an increase in tool cost. In Phase I, the feasibility of coating individual WC grains with the proper thickness of cobalt matrix was demonstrated. After consolidation, the problems of WC-WC particle contact and mixed carbide formation were found to be eliminated. Improved mechanical properties and performance over conventional micrograin carbides were obtained. The process permitted faster consolidation times and yielded, lower impurity content with less deleterious interaction between matrix and carbide, and a large reduction in the amount of cobalt required. In Phase II, the process for coating WC/mixed carbide powders with cobalt will be optimized. A 40% increase in tool life (reduced wear rate), at constant mechanical properties and lower cobalt content, and a 50% increase in tool toughness (and hence strength) at constant wear rates is expected.

Anticipated Results / Potential Commercial Applications as described by the awardee: Improved carbide tools should have a significant impact on reducing costs in the oil (drill bits), metals (inserts, tools), and machining industries (waterjet nozzles). Reduced cobalt content should also provide a substantial extension of current cobalt reserves.

CHEMICAL SCIENCES RESEARCH

34

On-Chip Infrared-Spectral Sensors by Superconducting Detector Arrays--Advanced Fuel Research, Inc., 87 Church Street, East Hartford, CT 06108; (203) 528-9806
Dr. David B. Fenner, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG05-93ER81507
Amount: $592,568

Conventional methods of infrared (IR) spectroscopy for analysis of chemical species are limited to instruments with low-throughput dispersive elements or to moving optics for transform spectroscopy. This project will apply a new, microoptoelectronic, on-chip-transform design to IR spectral measurement. Spectral transform of the IR will be accomplished by using a stepped-thickness array of interference filter plates microfabricated onto the detector-array chip assembly. The design will allow spectral analysis with both high-throughput and multiplex advantages. The sensor device will be fabricated on a 50 mm diameter silicon wafer substrate and will be small, compact, and rugged. The detectors are photothermal bolometers of high-temperature superconducting (HTS) films on silicon. In earlier work, the concept of silicon-wafer etalons introducing fringes into IR spectra measured with HTS bolometers was demonstrated; however, no progress was made toward demonstrating transform spectroscopy. The Phase I project completed the feasibility demonstration of the spectrometer by devising, modeling, and testing a design and microfabrication route; showed that silicon micromachining by lithographic reproduction and wet-etch processing will render large arrays of stepped-thickness plates in relatively few processing steps; and explored realistic model simulations of many device designs. In Phase II, 256-element arrays of stepped etalons and HTS detectors will be used to develop an effective on-chip spectrometer which can provide excellent resolution, sensitivity, and adaptability to many IR bands.

Anticipated Results / Potential Commercial Applications as described by the awardee: Small, on-chip transform spectrometers, with no moving or dispersive components, should provide improved field, and in-situ, chemical analysis for many energy systems, and opportunities for novel kinds of commercial devices. Compared with conventional methods (e.g., FT-IR), this design should be especially useful for compact and rugged monitoring sensors, with excellent flexibility of their specific functionality (bandwidth and resolution), and hence, wide market appeal.

35

Composite Plasma-Polymer Membranes--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. Walter C. Babcock, Principal Investigator
Dr. Walter C. Babcock, Business Official
DOE Grant No. DE-FG03-93ER81640
Amount: $599,916

Membranes are used in a growing number of industrial separations primarily because they are much less energy-intensive than competing technologies. However, currently available membranes are limited in applications in which aggressive chemicals (e.g., petrochemicals or organic solvents) are present, and they often do not exhibit sufficient selectivity to compete with other separation processes. If membranes were available that were resistant to organic chemicals and that exhibited the high selectivities that are possible with plasma polymer, the use of membranes would greatly expand. Plasma-polymer membranes offer a potential solution to

both problems due to their crosslinked amorphous structure. The main drawback to the use of plasma-polymer membranes has been that the most selective ones exhibit low permeabilities, and they are brittle in nature (again due to their high degree of crosslinking). Both drawbacks are overcome with very thin membranes (on the order 0.01 to 0.1µm), but thin membranes must be supported by microporous supports in a composite structure. Until now, the only microporous supports useful for supporting plasma-polymer membranes were made of conventional polymers that are not chemically resistant. Thus, it has not been possible to realize the full potential of plasma-polymer membranes for use in aggressive environments. Phase I demonstrated that solvent-resistant microporous support films can be made of plasma polymers. Composite membranes comprising a plasma-polymer selective layer on plasma-polymer microporous supports were prepared and were flexible enough to be practical. These composite membranes maintained their flux and selectivity after exposure to methylene chloride - a solvent that will dissolve or soften most conventional polymeric membranes.
Finally, an integrated coating system was designed to produce composite plasma-polymer membranes directly from suitable monomers. Phase II is directed toward demonstrating economical continuous production of a plasma-polymerized composite membrane, modularizing the membrane to demonstrate solvent-resistance and selectivity as well as practicability in a commercially acceptable form, and scaling-up the process with prototype commercial plasma-polymerization equipment in collaboration with the Phase II/Phase III partner.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful development of the composite membranes should open a wide range of industrial separations to treatment with energy-efficient membranes that are not now possible. Such applications include hydrogen recovery in refineries, production of nitrogen and oxygen from air, dehydration and sweetening of natural gas, separation of olefins from paraffins, separation of aliphatics from aromatics, and treatment of waste streams in the chemical process industry. The project should also lead to the development of a new type of material: a microporous plasma polymer that should be useful in other filtration applications and as a composite material with novel properties.

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Multiple Air Pollutant Emissions Removal by the Use of a Single Chemical Additive--
Energy and Environmental Research Corporation,
28 Mason, Irvine, CA 92718; (714) 859-8851
Dr. Vladimir Zamansky, Principal Investigator
Dr. William Randall Seeker, Business Official
DOE Grant No. DE FG05-93ER81538
Amount: $600,000

Air pollution control technologies for NO_x removal are limited by the relatively inert nature of NO. This difficulty can be overcome by oxidation of NO to much more reactive NO_2. Since flue gas desulfurization systems are required for SO_2 removal after combustion of sulfur containing fuels, and it has been proven that NO_2 can be removed efficiently by SO_2 scrubbers, the conversion of NO into NO_2 becomes a promising strategy for combined NO_x and SO_x removal. A large number of wet and dry scrubbers are already installed in stationary combustion sources or are planned for the near future. Therefore, a process that promotes NO_x removal simply through the injection of chemical additives into combustion gases could have a significant impact on air pollution control strategies. Phase I demonstrated the feasibility of a novel concept: gas phase multiple air pollutant emissions removal by injection of a single chemical additive into combustion gases with reaction times, temperatures, and other conditions in the practical range for its application in stationary combustion sources. Chemical kinetics calculations and experimental data obtained in a laboratory-scale flow reactor and in a pilot-scale Boiler Simulator Facility (BSF) demonstrate that this additive, injected into combustion gases at specific conditions, efficiently (up to 90-95%) converts major gaseous air pollutants (unreactive NO, corrosive SO_3, unburned CH_4, and some amount (20% of CO) to NO_2, SO_2, and CO_2. In Phase II, the additive will be injected alone and in a methanol mixture using two types of fuels, natural gas and coal. Two potential applications will be studied and demonstrated: (1) NO_x, SO_2 and hydrocarbons removal from exhaust of coal firing and (2) NO_x and hydrocarbons removal from exhaust of stationary gas engines of water treatment facilities. The objectives of the Phase II project include: optimization of the separate components of the technology for all applications; pilot-scale simultaneous removal of multiple air pollutants; pilot-scale demonstration of an integrated process including reburning, urea injection, additive/methanol injection, and combined SO_2/NO_2 scrubbing; and economic and market analysis.

Anticipated Results / Potential Commercial Applications as described by the awardee: The process should make it possible to implement a simple, effective, and flexible control of major gaseous air pollutants emanating from combustion sources. There is no risk of dangerous compound formation from the additive. The process should be simply incorporated in combination with other NO_x to a very low level. The process should decrease corrosion of combustion equipment and increase efficiency of power plants.

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Improved Coated-Metal Hydrogen Extraction Membranes--REB Research and Consulting, 25451 Gardner, Oak Park, MI 48237; (810) 547-7942
Dr. Robert E. Buxbaum, Principal Investigator
Dr. Robert E. Buxbaum, Business Official
DOE Grant No. DE-FG02-93ER81625
Amount: $599,314

Palladium-coated refractory-metal membranes are being developed for hydrogen extraction from chemical industry gas mixtures. The need for better hydrogen extraction membranes is particularly severe in refineries for the production of reformulated gasoline and for membrane-reactor use. Palladium-based membranes have been used for decades in hydrogen extraction because of the combination of high permeability and good surface properties, and because palladium, like all metals, is 100% selective for hydrogen transport. Although several stronger, cheaper refractory metals have higher permea-bilities than palladium, they are not ordinarily used for hydrogen extraction because their poor surface properties reduce hydrogen transport. It has been shown that coating these metals with palladium removes the surface barriers. The resulting membranes show hydrogen fluxes more than ten times greater than achievable with palladium and greater than achievable with polymers or comparable ceramics. Membranes of this sort have run successfully for as long as 10,000 hrs in a nuclear reactor experiment. Phase I demonstrated that large, 18 inch, thin-walled membranes could be fabricated which would meet or exceed all of the benchmark goals (100% selectivity, a minimum permeance of 0.0014 $\text{mol/m}^2\text{sPa}^{1/2}$, and less than 50% deterioration in one month of operation), suggesting highly economical hydrogen extraction for use with refinery and technical gas mixtures. In Phase II, palladium-refractory composite membranes will be fabricated and large hydrogen extraction will be demonstrated in the presence of industrial gas mixtures with realistic pressure and temperature transients. To be economically successful, the membranes must show: no leaks, cracks, or loss of selectivity and no significant deterioration, coking, or fouling in 6 months of operation with commercial gas mixtures.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project should move palladium-coated metal membranes from the laboratory and limited nuclear reactor use towards non-nuclear use in refineries and chemical plants. These membranes should be very economical for commercial hydrogen recovery for the production of reformulated gasoline, for membrane reactors, and for the production of ultrahigh purity hydrogen, e.g. for mobile, solid-state fuel cells.

MATERIALS SCIENCES INSTRUMENTATION

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An In-Situ Particle Sensor for Metal Forming Processes--Advanced Fuel Research, Inc., 87 Church Street, East Hartford, CT 06108; (203) 528-9806
Dr. Peter A. Rosenthal, Principal Investigator
Dr. Peter R. Solomon, Business Official
DOE Grant No. DE-FG05-93ER81594
Amount: $595,070

Numerous processes are being developed for manufacturing advanced composites which incorporate ceramics, polymers, metals and/or metal alloys. The success of these manufacturing processes is critically dependent on the ability to both monitor and control the processing conditions. Of particular interest is the development of powdered metals as a source material for a variety of metal forming processes, such as plasma spray, sintering and hot isostatic pressing. However, a lack of sensors is slowing the development of the powder technology. The Phase II project will continue the development and field testing of a metal powder smart sensor which can be employed in the hot particle forming plume, in the flowing stream of formed particles, and as part of a sizing system to characterize collected particles. The technique employs Fourier transform infrared (FT-IR) spectroscopy to differentiate the scattering of various particle sizes. FT-IR Scattering (FTIRS) spectroscopy relies on the wavelength and angular dependence of light scattering, rather than the angular dependence alone as seen in other techniques. In addition, FT-IR emission spectroscopy in combination with FTIRS offers a unique capability for particle temperature measurements in the plume. In Phase II, improved FT-IR particle analyzers will be developed and field tested. The instrument development will include: adoption of a state-of-the-art high speed FT-IR spectrometer design to reduce particle noise, coupling of two detectors to expand the useful wavelength range, refined optics to couple the instrument to the metal powder facility, and improved fast data acquisition and analysis algorithms applicable to high-rate forming processes. The instruments will be extensively tested both in the lab and in field tests at the National Institute of Standards and Technology metal powder facility.

Anticipated Results/Potential Commercial Applications as described by the awardee: The instrument should measure particle size and temperatures in hot multi-phase media. The instrument could have a pervasive impact on many large scale industrial materials processes using metal powders, ceramic powders, titanium oxide particles, polymers, plasma spray forming, stack gas monitoring, furnaces, lime kilns, paper manufacturing, coal combustion and hazardous waste disposal. When fully implemented, the economic impact from metal, ceramic, and titanium oxide powder production alone could exceed one billion dollars in savings from reduced waste.

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Development of a High Spatial Resolution Neutron Detector--BioTraces, Inc., 7986 Lakecrest Drive, Greenbelt, MD 20770; (301) 345-3279
Dr. A. K. Drukier, Principal Investigator
Dr. A. K. Drukier, Business Official
DOE Grant No. DE-FG05-93ER81602
Amount: $472,688

This project consists of the development of a new class of high spatial resolution neutron detectors based upon superconducting energy sensitive structures. A detector with a few square centimeter area, excellent spatial resolution, and high detection efficiency will be developed. The crucial component of this detector will be a large array (2048 x 2048) of superconducting sensors deposited on the surface of a neutron absorber (e.g. boron, boron nitride, or lithium hydride) which will act as a neutron-to-alpha particle "converter". Such a detector can attain a spatial resolution of a few tens of microns with a reasonable number (≤256) of readout channels. It is believed that a neutron detector with the following parameters can be developed: size - 20 cm x 20 cm; spatial resolution - better than 50 microns; detection efficiency - greater than 80% for thermal neutrons; temporal resolution - nanoseconds; background - at least thousand-fold suppression of photonic background.

Anticipated Results / Potential Commercial Applications as described by the awardee: Applications of radiation-hard, high spatial resolution visible/ultraviolet/X-ray detectors have a commercial potential exceeding hundreds of millions of dollars. Furthermore, this project should indirectly facilitate development of gamma-ray detectors for Nuclear Medicine with a market estimated to be over a billion dollars annually. Extensions to detection of gamma-rays and neutrons with superior stopping power are straightforward. For example, the next generation of Position Emission Tomography and Single Photon Emission Computed Tomography devices for Nuclear Medicine may represent a market with potential of over a hundred million dollars in the next decade.

40

A High Resolution Scintillator-Based Neutron Detector--Nanoptics, Inc., 3014 Northeast 21st Way, Gainesville, FL 32609; (904) 378-6620
Dr. Won Y. Choi, Principal Investigator
Dr. James K. Walker, Business Official
DOE Grant No. DE-FG05-93ER81600
Amount: $600,000

A new transparent scintillator material with high Boron 10 content has been developed which has superior characteristics for neutron detection systems. The material has 15 times the thermal neutron absorption efficiency compared to an existing available plastic scintillator. The new scintillator is also brighter than the existing scintillator and equally fast in its time response. The high neutron absorption efficiency will permit the use of much thinner plates of plastic scintillator which will reduce parallax errors in position resolution. Due to the very high neutron absorption per unit length in the new plastic, the gamma-ray background is correspondingly reduced because of the thinner plates which are required. This project will develop the capability to fabricate large, thin, uniform thickness plates of the plastic scintillator. To provide the highest spatial resolution, fiber optic type plates will also be fabricated. In this way, spatial resolution of approximately 8 microns will be achieved. Three prototype detectors will be constructed. The advantages of high spatial resolution, high neutron detection efficiency, high brightness, and high counting rate of the new scintillator will permit more effective use of the new high flux neutron facilities coming into operation worldwide.

Anticipated Results / Potential Commercial Applications as described by the awardee: Several National laboratories in the USA, Europe, and Japan, have major neutron scattering experimental facilities and should benefit from use of this advanced neutron sensitive plastic scintillator. Industrial neutron radiography for Non-Destructive Examination should also be a substantial market for the scintillator. International inspection of weapons grade nuclear material and accountancy of waste radioactive material at storage facilities represent further applications of the highly neutron sensitive plastic.

HIGH PERFORMANCE COMPUTING RESEARCH

41

A Rapid Calculation of the Coulomb Field in Large Molecules--Q-Chem, Inc., 7520 Graymore Road, Pittsburgh, PA 15221; (412) 268-1056
Dr. Benny G. Johnson, Principal Investigator
Dr. Benny G. Johnson, Business Official
DOE Grant No. DE-FG05-93ER81643
Amount: $561,650

Recently there has been a rapidly growing interest in Density Functional Theory (DFT) as a general procedure for predicting physical properties of molecules. This procedure is relatively inexpensive compared to traditional correlated methods. For the largest molecular systems whose study is feasible by the current DFT programs (several hundred atoms), the treatment of the Coulomb interactions, with its quadratic cost in system size, is computationally dominant. In order to be able to perform calculations on truly large molecules, a breakthrough in the scaling of the Coulomb contribution is required. The Fast Multipole Method (FMM) of Greengard is a method capable of evaluating the interactions of a collection of point particles to within a given error tolerance in an amount of computation which is linear in system size. Since the FMM is formulated to treat discrete distributions, it has been profitably applied in numerous areas of classical mechanics. But one important field of study where the FMM could not be applied is electronic structure theory. During Phase I, a generalization of the FMM to continuous charge distributions, the Continuous Fast Multipole Method (CFMM), was developed. A prototype CFMM implementation was interfaced with a quantum chemistry software package. The estimation of the "crossover point" at which the CFMM becomes faster than the conventional approach for evaluating the Coulomb matrix is a system with roughly 15-20 heavy atoms. This has very encouraging implications for significantly expanding the scope of chemical problems accessible by DFT. Phase II will refine the performance and extend the capabilities of the initial prototype program. In particular, the CFMM implementation will be extended to parallel architectures. Since the original FMM was demonstrated to be well-suited for parallelism by a variety of workers in the classical context, the efficient implementation of a parallel CFMM is not expected to be difficult, and would further broaden the range of tractable molecular systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The research should allow highly accurate density functional calculations to be carried out on much larger molecular systems than is possible with current techniques and programs. This could be of considerable value to researchers in computational quantum chemistry and physics at universities as well as industrial and government facilities.

TECHNOLOGY AND INSTRUMENTATION FOR HIGH ENERGY ACCELERATORS

42

A High-Performance Cryogenic Heat Exchanger--
Creare, Inc., P.O. Box 71, Hanover, NH 03755; (603) 643-3800
Dr. Javier A. Valenzuela, Principal Investigator
Mr. Robert A. Hickin, Business Official
DOE Grant No. DE-FG02-93ER81537
Amount: $599,756

Recuperative heat exchanges are key components in refrigeration systems used to cool superconducting devices in high energy physics research and in industry. Present plate-fin heat exchangers have an effectiveness around 0.97 and steam pressure drops of several percent. Approximately half the losses in the cryogenic refrigerator are directly attributable to ineffectiveness and pressure drop in the heat exchangers. Moreover, large and expensive vacuum enclosures and vacuum pumping systems are required to house and thermally isolate the heat exchangers. Development of a high performance cryogenic heat exchanger has the potential for decreasing heat exchanger losses by a factor of 3 and decreasing the heat exchanger size by a factor of 10 or more. Performance gains will be achieved through a novel core configuration which minimizes axial conduction losses in the metal and allows a very compact design. Phase I demonstrated the feasibility of the concept by performing a thermal design of the heat exchanger and testing the key fabrication steps. Phase II will fabricate and test a full scale heat exchanger designed to meet the requirements of laboratory and industrial helium refrigerators and liquefiers.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned heat exchanger should result in a major reduction in the operating expenses of cryogenic refrigerators. Improved heat exchanger performance should decrease input power by 30 to 50 percent and could also eliminate the need for using liquid nitrogen pre-cooling. In addition to laboratory cryocoolers, the heat exchanger could have widespread commercial applications in areas such as: industrial gas separation, superconducting-magnet ore separation, high-temperature superconducting energy storage systems, mobile oxygen separation, and air conditioning systems, to name a few.

43

A Microwave Power Combiner for a Cluster Klystron--DULY Research, Inc., 1912 MacArthur Street, Rancho Palos Verdes, CA 90732; (310) 548-7123
Dr. David U. L. Yu, Principal Investigator
Dr. David U. L. Yu, Business Official
DOE Grant No. DE-FG03-93ER81573
Amount: $600,000

Phase I has demonstrated the feasibility of a baseline design concept of a cluster klystron output combiner. The novel concepts of a coaxial traveling wave output coupler and a multiport power combiner form the baseline for Phase II. The objective of this project is to produce an engineering design and hardware for a compact and efficient power extractor and a combiner for a cluster klystron. Frequency- and time-domain electromagnetic simulation codes and direct scattering matrix (S-matrix) solvers, as well as a new method developed during Phase I to calculate the complete S-matrix for a multiport microwave network, will be used for precise design calculations of the properties and performance characteristics of the following components: (1) a coax-to-rectangular waveguide coupler, including a choke joint to suppress the asymmetric transverse electric (TEll) mode and (2) a 3-beam transverse magnetic (TM01) mode power combiner. These components will be designed, fabricated, and cold tested for an initial proof-of-principle experiment to be conducted at Brookhaven National Laboratory. In addition, the analysis and design of a 6-beam power combiner for a future cluster klystron and of a TM01 to TE01 mode converter for power distribution will be performed.

Anticipated Results / Potential Commercial Applications as described by the awardee: The microwave power extractor/combiner can be used in a multiple-beam klystron as a compact and efficient power source to meet the requirements of future linear colliders. The combiner is a key component of the cluster klystron. The cluster klystron can also be used to power a compact accelerator for industrial, medical, and research applications. Long-pulse, high-power microwaves have potential uses in defense and communications. In addition, analytical methods developed in this project should have wide applications in the design of many microwave components.

44

A 17 Gigahertz High Gradient Accelerator Structure for a Picosecond Bunch, 30 MeV Electron Source--Haimson Research Corporation, 3350 Scott Boulevard, Building 60, Santa Clara, CA 95054-3122; (408) 988-6007
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-93ER81487
Amount: $600,000

Electron accelerator linear collider studies continue to support earlier contentions that the most favorable choice of linac frequency is in the range of 10 to 20 Gigahertz (GHz). Considerable interest exists in 17 GHz linear collider technology, and research activities are in progress at MIT and in private laboratories investigating commercial applications of high frequency linacs. However, there are no accelerator waveguide structures presently available to support 17 GHz high gradient accelerator research. (Accelerator structure development for linear colliders is at 11.4 GHz in the USA and Japan, and at 14 GHZ in Russia.) Phase I investigated the microwave parameter and injection beam optics requirements of 17 GHz high gradient structures; established a preferred structure design and the specifications of a matching HV injection system for high resolution linac performance with bunch widths less than 5 degrees (approximately 1 picosecond); and prepared overall layout drawings of a high power test facility for evaluating the RF performance of the structure. The objective of this project is to: (1) fabricate a 94 cavity quasi-constant gradient, 50 MeV/m, 17 GHz accelerator structure that will provide high resolution beam performance from 15 to 30 MeV, with bunch widths less than 1 picosecond; (2) design and construct the associated high vacuum, cooling, and mechanical subsystems and the RF beam diagnostics, including a 30 degree bent beam spectrometer system; and (3) install the accelerator structure and associated subsystems in a shielded test facility and conduct high power tests to evaluate the RF performance and dark current characteristics of this prototype 17 GHz high gradient accelerator structure.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that this project will result in a high gradient linac RF test facility operating in a new frequency regime to support 17 GHz linear collider accelerator research. With the use of a matched HV injector, the linac structure should be able to demonstrate high resolution performance with bunches less than 1 picosecond over a range of beam energies from 15 to 30 MeV for advanced accelerator and free electron laser applications and for research in high RF power generation at sub-millimeter wavelengths.

45

Mode-Locked Pulse Amplifiers for Photocathode Illumination--Lightwave Electronics Corporation, 1161 San Antonio Road, Mountain View, CA 94043; (415) 962-0755
Mr. Martin Gifford, Principal Investigator
Dr. Robert L. Mortensen, Business Official
DOE Grant No. DE-FG03-93ER81489
Amount: $584,505

Mode-locked laser pulses are required for generating bursts of electrons from photocathodes. The photocathodes are typically illuminated with 10-100 micro-Joules per pulse of energy in the ultraviolet. Recently, diode-pumped Nd:YLF and Nd:YAG mode-locked oscillators with low timing jitter have been developed that are the preferred front end for the photocathode illumination systems. The application requires selecting a 1-10 microsecond long section (macropulse) of the mode-locked pulse train for amplification by 40-60 decibels (dB); this is currently achieved with lamp-pumped amplifiers. This project will investigate laser diode-pumped amplifier technology that will lead to a more reliable, efficient, compact, and stable laser than lamp-pumped systems. The following will be characterized: a diode-pumped multi-pass pre-amplifier design that will increase pulse energies from the mode-locked oscillator by 30 dB, and a quasi-continuous wave (CW) diode-pumped power amplifier that will provide further amplification by approximately 10 dB. An investigation will be made of the performance of CW diode-pumped regenerative amplifiers as a means of generating millijoule-level pulse energies at kilohertz repetition rates. A study will be done of pulse broadening effects in amplifiers for a variety of gain materials including Nd:YAG, Nd:YLF, Nd:YVO_4 and Nd:Glass. The two-fold objective of this project is to develop an integrated diode-pumped laser system for generating high energy macro-pulses and to characterize a new high power diode-pumped regenerative amplifier.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will develop an integrated diode-pumped laser system capable of serving photocathode applications better than present systems. This project will also characterize a diode-pumped regenerative amplifier that produces pulses with approximately 100 megawatt peak power; these systems have significant commercial potential and should have applications in photocathode illumination, spectroscopy, biology, and chemistry.

46

Development of a 100 Megawatt X-Band Relativistic Klystron Amplifier--MDS Company, 1955 Mountain Boulevard, Suite 101, Oakland, CA 94611; (510) 339-0957
Dr. Patrick Ferguson, Principal Investigator
Dr. Patrick Ferguson, Business Official
DOE Grant No. DE-FG03-93ER81491
Amount: $600,000

Future high gradient linear particle colliders operating at X-band with acceleration gradients exceeding 100 Mev/m require radio frequency (RF) sources capable of generating high peak power at high efficiency. To meet this need, analysis, computer simulation, and RF testing produced several accomplishments: (1) a 100 MW relativistic klystron amplifier (RKA) operating at 11.424 GHz with 120 HZ pulse repetition rate and a minimum pulse width of 1.0 microsecond was designed and simulated based on conventional klystron theory. (2) A low perveance electron gun capable of generating a solid electron beam from a thermionic cathode operating in ultra high vacuum was designed. (3) Through computer simulation, an electron beam-electromagnetic wave interaction circuit capable of producing 100 MW with a saturated gain of 58 dB and an efficiency of 42% was designed, fabricated and RF tested. (4) A four cavity output circuit capable of efficiently extracting the fundamental RF power from the electron beam was designed, fabricated, and RF tested. (5) A ceramic vacuum window capable of transmitting more than 100 MW at 11.424 GHz at a pulse width of 1.0 microsecond was designed and RF tested. In Phase II, the mechanical design, fabrication and RF testing of the various subassemblies will be completed, and a 100 MW X-band RKA will be assembled and tested. A test diode, consisting of the electron gun and collector, will be fabricated to verify the high voltage operating parameters. After the successful operation of the test diode, the RF interaction circuit between the electron gun and the collector will be installed and the completed RKA will be baked out. Both the test diode and the RKA will be tested at Phillips Laboratory, Kirtland AFB, New Mexico.

Anticipated Results / Potential Commercial Applications as described by the awardee: Anticipated results are the successful design of a 100 MW X-band high duty klystron. This klystron should be a high power source for future linear colliders and for high gradient electron accelerators for commercial applications. With additional gain cavities, this klystron should be broadbanded for military applications.

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Magnetron Arrays for Linear Colliders--Mission Research Corporation, 735 State Street, P.O. Drawer 719, Santa Barbara, CA 93102-0719; (805) 963-8761
Dr. Richard S. Smith, III, Principal Investigator
Mr. Scot R. Fries, Business Official
DOE Grant No. DE-FG03-93ER81492
Amount: $599,925

Phase I demonstrated many key aspects of the approach for using arrays of inexpensive, low-voltage, reliable magnetrons in the Next Linear Collider (NLC) and other applications requiring high microwave power levels. An array of eight magnetrons was phase locked and efficiently power combined using a technique which requires only low levels of radio frequency (RF) priming power and provides high magnetron coherency to a reference source from the very start of the pulse. Circuit codes were used to partially demonstrate a unique modulator approach which will allow extremely flat pulses at very low cost and high efficiency. A modulator, employing major aspects of this approach, was experimentally demonstrated to provide several hundred nanoseconds of very constant magnetron-array output phase. Two methods were experimentally demonstrated for controlling the phase of the magnetrons, either to keep the phase flat or to allow a controlled amplitude ramp, as needed for the NLC. Other aspects of the approach were also investigated and at least partially verified. Phase II will demonstrate most of the key aspects of the approach at much higher power levels. A modulator of the type investigated in Phase I will be built and used to pulse arrays of currently-existing high-power magnetrons. Phase and amplitude stability and controlled amplitude ramping will be demonstrated at the megawatt power level. Attempts will be made to demonstrate magnetron cold starting (requiring no cathode heater power). In addition, there will be a joint effort with microwave tube manufacturers to develop an NLC prototype magnetron which will also be tested in a small array.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project should go very far toward proving the feasibility of magnetron arrays in this and other applications, and should facilitate a Phase III demonstration at full NLC-array power. Besides the commercial market represented by the NLC and other research accelerators, possibilities for other commercial applications exist in the medical-accelerator and chemical-processing industries.

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A Modified Inverse Free-Electron-Laser Accelerator--Omega-P, Inc., 2008 Yale Station, New Haven, CT 06520; (203) 458-1144
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG05-93ER81514
Amount: $600,000

The objective of this project is to design and demonstrate a prototype of an accelerator to furnish 5 ps bunches of 10^9 electrons at energies from 5 to 35 MeV. This accelerator, based on a modified version of the inverse free-electron-laser principle, functions by trapping electrons in moving ponderomotive buckets that form through the beating between a traveling electromagnetic wave and a standing helical wiggler magnetic field. Since the structure that supports the accelerating fields has a smooth wall, it is not expected to induce wake fields that can disrupt the accelerating beam. Phase II experiments will employ a ~10 MW, 14.28 GHz radio frequency (rf) source, and a variable-pitch, variable-radius, helical wiggler. Parameters for the rf waveguide and the magnetic wiggler will be determined by 1-D and 3-D nonlinear computer simulations. Modifications beyond other versions of the inverse free-electron-laser accelerator include a traveling- or standing-wave resonant cavity to enhance the acceleration gradient and an rf gun injector to maximize the trapping fraction, reduce the longitudinal beam emittance, and reduce beam loading. Continued analysis will also allow improved design procedures for achieving higher accelerating gradients and lower beam emittances.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated operating parameters of the prototype MIFELA indicate that commercial versions of the accelerator could be marketed for $1 million or less. This should allow individual investigators to perform advanced accelerator R & D in university and small-business laboratories. It should also provide a competitive alternative to the rf linac for applications in medicine, oil and gas prospecting, and food sterilization.

ACCELERATOR TECHNOLOGY FOR NUCLEAR PHYSICS

49

An Intensity and Position Monitor for Particle Beam Diagnostics--Quantum Magnetics, Inc., 11578 Sorrento Valley Road, San Diego, CA 92121; (619) 481-4015
Dr. Alan L. Singsaas, Principal Investigator
Mr. John P. Sanders, Business Official
DOE Grant No. DE-FG03-93ER81583
Amount: $599,634

With the development of a new generation of accelerators for nuclear physics, such as the Continuous Electron Beam Accelerator Facility (CEBAF) and the Relativistic Heavy Ion Collider (RHIC), a corresponding need has arisen for a new generation of diagnostic tools for non-destructively monitoring the intensity and position of the particle beams. This project represents a new approach to the measurement technique for position and intensity monitoring. The operating principle differs from existing stripline and capacitive antennas, tuned to detect the electric field from the beam, in that the magnetic field from the current is measured directly in the pickup loops. This is accomplished through the use of a closed superconducting loop coupled to a Superconducting Quantum Interference Device (SQUID). Advantages include: (1) a much lower limit on measurement threshold due to the extreme sensitivity of SQUIDs for magnetic field measurements, (2) a greatly extended dynamic range, and (3) a greater flexibility for integrating the system into the beam pipe because of the small dimensions of the pickup loops. Phase I determined the specifications for the system, investigated the feasibility of the technique, and developed a design for a prototype beam position and intensity monitor for use at CEBAF. In this project, the fabrication of a fully functional prototype will be completed for integration into the beamline at CEBAF. The system's ability to perform to its specifications will be verified by actual tests of the prototype at CEBAF, confirming its ability to meet all technical requirements specified by the CEBAF staff for position and intensity measurement. The approach will result in a state-of-the-art system that provides enhanced performance over existing devices and is adaptable to a wide range of design parameters such as active probe dimensions and measurement sensitivity.

Anticipated Results/Potential Commercial Applications as described by the awardee: The position and intensity monitoring system for accelerator charged particle beams should provide enhanced performance over existing devices due to its increased sensitivity and greater adaptability. Once the potential of the technology has been demonstrated through this first system, its usefulness for many other beam monitoring applications should become apparent. Similar systems developed in Phase III could be used for measurements at other charged particle beam accelerators and upgrades to existing accelerators for nuclear and particle physics. A need exists for such a device in DOE laboratories, in other government research facilities, and in future foreign and domestic accelerator systems. Experiments and diagnostics in progress today and planned for the future at accelerators, such as CEBAF, RHIC, as well as future superconducting accelerators, synchotron light sources, storage rings, and linear colliders, should benefit from the technology.

PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

50

Radiation Resistant Radio Frequency Feedthrough Insulators for Fusion Applications--
Composite Technology Development, Inc., 2400 Central Avenue, Suite H, Boulder, CO 80301; (303) 447-2226
Dr. James B. Schutz, Principal Investigator
Dr. Naseem A. Munshi, Business Official
DOE Grant No. DE-FG03-93ER81586
Amount: $600,000

Advanced ceramic matrix composite materials have been demonstrated to perform better than materials commonly used for radio frequency (RF) feedthrough insulators. Current Ion Cyclotron Radio Frequency (ICRF) designs are compromised because they must be configured to accommodate the operating envelope of alumina within the anticipated fusion environment. The development of an insulating material with superior performance to alumina, under the prevailing operating conditions, will enable the ICRF system design to be directed toward greater system performance. Ceramic composites have the potential to fulfill this goal. During Phase I, representatives of several broad categories of monolithic and composite ceramic materials were obtained from a variety of sources. These included several grades of alumina, reinforced zirconias, magnesia-alumina-silica (MAS) compositions, and various nitride and carbide ceramics. Preliminary fabrication of ceramic composites was demonstrated using alumina and MAS ceramics reinforced with chopped alumina fiber and particulates. This project will develop and fully characterize materials suitable for use in ICRF feedthrough applications, and which surpass the performance of current materials such as monolithic alumina. A program has been outlined which progresses from fabrication of test materials to prototype fabrication. In addition, because radiation effects are of utmost concern for components in fusion devices, radiation exposure studies are planned to include post-irradiation evaluation of materials. However, some effects are due to the interaction of electric fields in a radiation flux and can only be evaluated by in-situ testing. A survey of currently available radiation sources was performed to establish sites where both types of effects can be evaluated. Successful development of this ceramic insulating material should impact the design of several systems for the International Thermonuclear Experimental Reactor, including ICRF, Electron Cyclotron Resonance Heating (ECRH), and various diagnostics. This material can also be used for other fusion facilities such as the Tokamak Physics Experiment and IGNATOR (an Italian fusion device).

Anticipated Results/Potential Commercial Applications as described by the awardee: The fabrication equipment, processes developed, and characterization methodology should be applicable to other frequency regimes, including electron cyclotron (EC) and lower hybrid (LH) RF heating systems, as well as for other diagnostic and in-vessel components. This project should directly affect the ability of the United States to remain at the forefront of materials research and development in support of large-scale fusion devices.

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Helium-Cooled Divertors with Low Pumping Power and Simple Fabrication Techniques--Creare, Inc., P.O. Box 71, Hanover, NH 03755; (603) 643-3800
Dr. Michael G. Izenson, Principal Investigator
Dr. James A. Block, Business Official
DOE Grant No. DE-FG02-93ER81628
Amount: $599,918

The objective is to develop technology for helium cooling that will greatly increase the safety of future Tokamak reactors such as International Thermonuclear Experimental Reactor (ITER) or Tokamak Physics Experiment (TPX). Divertors in these reactors receive high heat fluxes (order 5 MW/m^2) for long pulse or steady state operation and must be actively cooled to prevent excessive temperatures. Unlike water-cooled designs, a helium-cooled diverter would be stable because small leaks would have little impact on safety or operation. However, practical techniques for cooling high heat flux components using helium gas are not yet available. In Phase I, feasibility of highly efficient helium heat exchangers was demonstrated. These heat exchangers were shown to: efficiently cool high heat flux, plasma-facing components with low pumping power; be amenable to mass producion in large sizes suitable for diverters in large Tokamaks; enable high helium outlet temperatures that simplify system design; and be fabricated from prototypical copper alloys or from low-activation materials such as aluminum. The key to achieving efficient cooling with helium at high heat fluxes is the development of a novel configuration for the Normal Flow Heat Exchanger (NFHX). NFHX structures with very low pumping power requirements (0.2% of the heat removed) can be fabricated in large sizes from copper alloys. In Phase I, fabrication techniques were demonstrated using prototypical materials, heat transfer tests were conducted to demonstrate high thermal performance and verify design methods, and computational fluid dynamic (CFD) analysis of helium-cooled NFHX structures were performed under prototypical conditions in large Tokamak reactors. The CFD analysis showed that the planned heat exchanger configuration can achieve high performance in divertors of large Tokamaks. In Phase II, the helium-cooled NFHX will be developed to the point of practical commercial-ization. Several heat exchangers will be designed and fabricated in prototypical configurations of large fusion devices such as ITER. These samples will be tested at the Electron Beam Test System at Sandia National Laboratory. First-order system models will be developed for divertor cooling systems to quantify the system benefits of the NFHX configuration.

Anticipated Results/Potential Commercial Applications as described by the awardee: Heat exchangers will be developed that should efficiently cool high heat flux components using a single-phase gas. For the U.S. fusion energy program, the benefits would be (1) improved safety because water coolant can be eliminated from the divertor, and (2) low cost because the fabrication techniques are simple and can be easily scaled up to large sizes. Commercial applications could include: components for the ITER, air-cooled heat sinks for power electronics devices, and thermal management for high heat flux applications such as X-ray targets and leading edges on hypersonic aircraft.

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Methods of Improving Internal-Tin Niobium-Tin for Fusion Applications--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06704; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. B. A. Zeitlin, Business Official
DOE Grant No. DE-FG02-93ER81513
Amount: $600,000

The overall objective of this work is to provide the Tokamak Physics Experiment (TPX), the International Thermonuclear Experimental Reactor (ITER), and similar projects with an improved, reliable, and economical high field niobium-tin (Nb_3Sn) multifilamentary conductor strand made by the internal-tin process. To develop optimized heat treatments for these fusion applications, an effort will also be made to determine the reasons for property changes taking place after various heat treatment cycles. Other objectives of Phase II are as follows: (1) While strand meeting high performance specifications has been made, the margins by which it does are small, and there is a definite and urgent need to widen them. Phase I showed that adding Ge to the matrix of a tubular tin source (TTS) conductor improves the current density throughout the field range (8T - 12T). Since this type of conductor is not suitable for TPX/ITER strand, an objective of Phase II is to prove that the matrix material containing Ge can be used in the tin-core strands used in these fusion applications. (2) Since cost reduction is also an important factor, the stabilizer billets will be scaled up to 203 mm (8 inches) diameter from the present 152 mm (6 inches) diameter size in an effort to reduce fabrication costs. (3) Chromium plating is presently used on strand to prevent sintering and to reduce transconductance. Many questions have arisen from the use of this material and a dual barrier approach was used in Phase I to show that the Residual Resistivity Ratio of chromium plated material can be made relatively independent of heat treatment. This approach will be modified in Phase II by removing the copper and developing techniques to produce a tantalum surface. (4) During Phase I it was determined that the losses exhibited by the wire are highly dependent on the ramp rate of the heating cycle and whether or not this cycle includes holds at intermediate temperatures. In Phase II an extensive investigation will be carried out to find an explanation for these effects.

Anticipated Results / Potential Commercial Applications as described by the awardee: This work should result in the development of a more reliable and economical high field material for ITER, TPX, and other high field magnet programs. Also the material should be available for use in high energy physics applications. In the commercial area, the improved material which will result from this work should be available for use in high field laboratory magnets.

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Advanced Nondestructive Evaluation for Quality Assurance of Divertor Plate Armor Tiles in Plasma Fusion Reactors--Karta Technology, Inc., 1892 Grandstand, San Antonio, TX 78238; (210) 681-9102
Dr. Satish M. Nair, Principal Investigator
Dr. G. P. Singh, Business Official
DOE Grant No. DE-FG05-93ER81647
Amount: $600,000

Reliability of bonded joints between the armor tile and the heat sink in divertor plates is a critical issue facing plasma fusion energy demonstration projects such as Tokamak Physics Experiment (TPX) and International Thermonuclear Experimental Reactor (ITER). Imperfections in these joints cause high thermal stresses which lead to the development and propagation of lateral cracks along the interface. The heat sink material stops functioning effectively, reducing its ability to cool the armor tile and causing meltdown of the tile and possible contamination. Hence, there is a critical need to develop and demonstrate Nondestructive Evaluation (NDE) methods to assure the reliability of these components. Candidate NDE technologies (including squirter and laser ultrasonic techniques, low frequency eddy current methods, X-ray CT and backscatter, and time-domain infrared radiometry) will be investigated by conducting a round robin experimental study using mockups of Beryllium/Copper and Carbon-Carbon/Copper tiles. The study will assess the abilities of the different NDE techniques to detect the following defects: (1) disbondments and cracking at the interface of both diffusion-bonded and braze-bonded Be/Cu and C-C/Cu armor tiles, (2) porosity in plasma-sprayed Be coatings, and (3) high residual stresses at the interface of both Be/Cu and C-C/Cu armor tiles. For each of these defect categories, the NDE technique to be applied and the minimum defect size detectable will be determined. Thermal cycle tests performed on specimens screened by the recommended NDE techniques should provide realistic fatigue life estimates for the tiles.

Anticipated Results / Potential Commercial Applications as described by the awardee: The results from this effort should be of considerable benefit to the design and development of plasma facing components in ITER and TPX. Besides improving reliability, the methods developed could provide designers information on NDE capabilities so that they can be factored into the design of these components. Commercial applications could extend to joints used in hypersonic airframe and space structures, cladded reactor pressure vessels, etc.

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A Neural Network-Based Disruption Alarm--Orincon Corporation, 9363 Towne Centre Drive, San Diego, CA 92121; (619) 455-5530
Dr. Gary L. Jahns, Principal Investigator
Mr. Richard L. Taylor, Business Official
DOE Grant No. DE-FG03-93ER81581
Amount: $599,970

Disruption avoidance is a major issue for future tokamaks such as Tokamak Physics Experiment (TPX) and International Experimental Thermonuclear Reactor (ITER). Phase I research demonstrated the feasibility of constructing a neural network-based disruption detector that outperforms a linear detector based on the Troyon criterion. In contrast to precursor detectors that give warning in the short time immediately before disruption, the neural network detector uses other parameters as additional discriminants. A database of time series data has been established for 40 parameters from 17 disruptive high-β Tokamak Fusion Test Reactor discharges. In one successful trial, the input parameters were reduced from 40 to 15 by examining the correlation of the parameters with β_p IP/aBT. Receiver Operating Characteristics (ROC) were used as the means of comparing the neural network performance to a simple detector based on a linear threshold in β_p IP/aBT: the neural network had a substantially better ROC quantified by higher figure of merit. The neural network detector also was able to estimate the final β_ps value with reasonable accuracy up to 300 ms in advance. Initial sensitivity analysis shows that the disruption level estimated by the network is influenced by profile shape factors and mode activity levels. The performance and predictive ability will be studied in Phase II with a larger database (eliminating the possibility of attributing the Phase I results to the neural network recognizing statistical anomalies in the present, smaller database). The two main thrusts of Phase II are to perform further development of the disruption detection methodology (including database expansion, neural network optimization, and physics exploration) and to implement a prototype system. The prototype system will incorporate modular hardware and a functional software environment that has been developed in other applications. The critical issue of processing lag time will be addressed by utilizing dedicated processors for both data handling and calculations. Timing tests using the Phase I data and neural network configuration, and executed on a dedicated processor, have shown that the feed-forward calculation can be done in 0.85 ms, rapid enough to make achievable the goal of 2-3 ms latency.

Anticipated Results/Potential Commercial Applications as described by the awardee: The work should provide new tools for exploring the causes of disruptions, and could produce an operational prototype system at an experimental facility. The project is planned as a component of the national TPX Physics R & D effort. The operational system should represent the cost-effective transfer of mature technology developed under defense funding to the fusion research arena. It is expected that demonstration of this technology in a fusion energy laboratory setting could stimulate similar applications to other tokamak control problems, opening the door to feedback control based on measurement of kinetic plasma parameters.

55

Dense, High Conductivity, Copper/Aluminum/Beryllium Functionally Gradient, Plasma Facing Components--Plasma Processes, Inc., P.O. Box 14524, Huntsville, AL 35815-0524; (205) 881-7572
Ms. Erin H. Richardson, Principal Investigator
Ms. Cheri M. McKechnie, Business Official
DOE Grant No. DE-FG05-93ER81563
Amount: $599,995

The Department of Energy and the International Thermonuclear Experimental Reactor are currently searching for a method for fabrication and in-situ repair of fusion reactor plasma facing components (PFCs). Vacuum Plasma Spray (VPS) is being investigated due to its telerobotic control features and ability to deposit materials of interest, e.g. Beryllium (Be). However, obstacles to the utilization of VPS for fabrication or in-situ repair of tokamak PFCs include poor properties of present VPS Be and potential contamination of the fusion reactor vacuum vessel by powder overspray. To rectify these obstacles, this project will produce a dense, high thermal conductivity, recrystallized structure of a three component (Cu/Al/Be) functionally gradient material utilizing innovative bell-contoured parallel flow nozzles and optimized vacuum plasma spray parameters. The parallel flow nozzles will increase deposition efficiency and decrease powder overspray, creating material deposits to near 100% densities. Optimized VPS parameters will achieve a recrystallized material grain structure which has shown higher conductivity, strength, and fatigue properties. As a final objective, a state-of-the-art powder reclamation system will be developed. This system will further reduce powder contamination of the tokamak vacuum vessel by reclaiming powder overspray at the workpiece. This reclamation system will also allow recycling of the metal powder waste thus making the VPS process even more cost effective and environmentally compliant.

Anticipated Results / Potential Commercial Applications as described by the awardee: Functionally gradient materials should be used in gas turbine, automotive, and diesel engines (thermal barrier coatings), rocket engines (combustion chamber jackets and liners), missile nose cones, boilers, heat exchangers, etc. High efficiency VPS nozzles should be used by commercial and government thermal spray applicators to improve their products. Powder reclamation system customers include nuclear and fossil fuel power generators needing in-situ repairs and industrial users of VPS. Commercial interest is so high that a firm order to purchase a powder reclamation intake manifold has already been received.

56

Niobium-Tin Superconducting Wire with Built-In Niobium Surface Coating to Limit Inter-Strand Eddy Current in Cables--Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545; (508) 842-0174
Dr. Dingan Yu, Principal Investigator
Ms. Elaine Drew, Business Official
DOE Grant No. DE-FG02-93ER81533
Amount: $599,978

The objective of Phase I was to evaluate the feasibility of developing a Niobium (Nb) surface coating technique to replace the existing hard chrome plating technique in the manufacture of Niobium-Tin (Nb_3Sn) strands for the International Thermonuclear Experimental Reactor (ITER) and/or the Tokamak Physics Experiment (TPX). Several ITER-type bronze-route Nb-coated Nb_3Sn strand samples were successfully fabricated. Results show that a continuous Nb layer as thin as about 2 microns can be formed on the surface of ITER/TPX strands by using this co-processing technique. This Nb coating prevents the ITER strands in a Cable-in-Conduit conductor from sintering during NB_3Sn reaction heat treatment. The additional magnetization hysteresis loss due to the Nb surface coating is negligible when compared to the loss from NB_3Sn filaments in the strand. This project will address the improvement of the co-processing technique and the optimization of Nb coating thickness based on the results of inter-strand resistance and eddy current loss measurements. In addition, Tantalum and Molybdenum surface coatings will be prepared and evaluated on ITER/TPX type strands using a similar technique. The most promising coating material and process will be selected and demonstrated in the ITER/TPX strand fabrication on a production scale.

Anticipated Results / Potential Commercial Applications as described by the awardee: Phase II will result in a new surface coating technique, which can be applied to ITER strand and other superconducting strand production where reduction of inter-strand eddy current losses is of great importance. The success of this project should expedite the ITER/TPX strand fabrication, reduce the strand cost, and improve the stability of superconducting magnets against inter-strand eddy current losses.

FUSION ENERGY SYSTEMS

57

An Innovative Approach for the Formation of Silicon Carbide/Silicon Carbide Composites--Lanxide Corporation, P.O. Box 6077, 1300 Marrows Road, Newark, DE 19714-6077; (302) 456-6216
Dr. William B. Johnson, Principal Investigator
Mr. Robert J. Ferris, Business Official
DOE Grant No. DE-FG05-93ER81517
Amount: $599,952

The objective of this project is to prepare and characterize both silicon carbide (SiC) particulate and fiber-reinforced SiC matrix composites using the directed metal oxidation process. In this process, a molten metal is oxidized to grow an oxidation reaction product into an adjacent filler of reinforcement material. Directed metal oxidation of molten Si to form SiC was demonstrated in Phase I using a fluorinated hydrocarbon, CF_4, as the oxidizing gas. SiC matrices were grown both in the absence of and in the presence of SiC fillers. The microstructures were typical of those observed in other directed metal oxidation systems (i.e., an interconnected ceramic structure interwoven with an interconnected metal phase, in this case Si-Fe alloy). Phase II will demonstrate the commercial potential for fusion applications of SiC matrix composites prepared by the directed metal oxidation process. The following tasks will be performed: modification of two vacuum furnaces already in-house in order to produce larger samples in higher quantity; preparation of both SiC particulate-reinforced SiC matrix composites and fiber-reinforced SiC matrix composites; optimization of growth conditions to maximize SiC content in the composite matrices; complete process characterization, including weight change from the reaction, visual observation, x-ray diffraction, optical and scanning electron microscopy of mounted cross-sections, and mechanical property measurement of the composites; and assessment of critical issues related to the use and commercialization of SiC matrix composites in fusion and non-fusion applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: The SiC matrix materials offer the potential for first wall, blanket, and divertor applications in plasma energy systems because of their low activation, short-term dose potential, low decay heat, and their high temperature properties. The processing approach should provide more cost-effective materials with improved properties for this application compared to current approaches. Inexpensive SiC/SiC composites could have multiple applications in the aerospace industry, e.g., as components in turbine engines.

58

Doping Silicon Carbide to Produce High Thermal Conductivity Silicon Carbide/ Silicon Carbide Composites--Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706; (602) 574-1980
Dr. Witold Kowbel, Principal Investigator
Dr. J. C. Withers, Business Official
DOE Grant No. DE-FG02-93ER81482
Amount: $600,000

Thermal management at high temperatures has become the limiting technology to a variety of advanced applications including fusion reactors, and a variety of commercial applications such as energy conversion, heat exchangers, engines and electronics. Silicon carbide (SiC) has a low thermal expansion coefficient and is stable in many high temperature environments, with a potential to significantly enhance its thermal conductivity through doping. Phase I demonstrated that boron or beryllium doping increased SiC thermal conductivity when prepared by chemical vapor infiltration or hot pressing. In particular, hot pressed, beryllium (Be) doped SiC/SiC composite had a thermal conductivity over 8.5 times state-of-the-art SiC/SiC composites. In Phase II, the thermal conductivity of SiC through doping will be optimized using processing of chemical vapor infiltration, hot pressing, and pyrolysis of polycarbosilane. The optimized doping-processing will be used to establish the relationship of thermal conductivity to mechanical properties for SiC/SiC composites. In addition, samples will be prepared to establish the effects of radiation on the properties of the doped SiC/SiC composites.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that SiC can be doped using several processing techniques to produce high thermal conductivity at 1000°C for use in SiC/SiC composites. Applications should include thermal management in fusion reactors and in commercial applications of energy conversion, heat exchangers, engine components, and electronics.

PLASMA DIAGNOSTICS

59

A Passive Optical Monitor for Tokamak Plasma Inhomogeneities--Science Research Laboratory, Inc.,
15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Stephen Fulghum, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-93ER81531
Amount: $599,968

The objective of this project is to develop a new, non-perturbing, optical diagnostic for the measurement of tokamak plasma fluctuation spectra in both the temporal and spatial domains. The instrument can be analyzed, in principle, as a form of an optical Doppler velocimeter which requires only incoherent light emitted by the plasma itself for its operation. The system can be adjusted to respond primarily to plasma fluctuations at a given spatial scale size, *k*, which move in a given direction transverse to the observation axis. The output signal is derived only from light emitted within the focal volume of the collection optics and is not a line-of-sight average. The signal itself is a single, time-varying voltage which is digitized at megahertz frequencies for the duration of the tokamak run. A Fast Fourier Transform of this signal provides the frequency spectrum for the plasma fluctuation at the set spatial frequency scale and transverse direction. The instrument will primarily be used to map the turbulence spectra in *k*-space which are needed to understand transport. It will also be able to map the direction of the local magnetic field since the fluctuation signal peaks in the direction perpendicular to the transverse projection of that field. In Phase I a prototype instrument was built and installed on the Alcator C-Mod tokamak at MIT to measure fluctuations in the edge plasma. To date, the instrument has successfully measured the frequency spectra of the H_α emission at two spatial frequencies and has shown the expected dependence on magnetic field direction. A derivation of the instrument's *k*-space transfer function has been completed as have signal-to-noise calculations. In Phase II, the measurements with the prototype instrument will be expanded to measure two *k* components simultaneously in the edge plasma. Additional instruments will be delivered to MIT which will provide automated selection of the *k* sensitivity and measurement direction as well as providing detectors and optics optimized for measurements of bremmstrahlung from the core plasma.

Anticipated Results / Potential Commercial Applications as described by the awardee: This instrument should provide localized measurements of plasma fluctuations and magnetic field direction with less setup effort and at lower cost than competing techniques as well as requiring less port space. Commercial prospects should be excellent for very low cost versions optimized to measure the velocity of flames, conveyor belts, and highway traffic.

ROBOTICS AND REMOTE OPERATIONS IN CIVILIAN NUCLEAR REACTOR FACILITIES

60

An Integrated Video and Gamma Ray Imaging System for Robots in Nuclear Environments--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172; (617) 926-1167
Dr. Michael R. Squillante, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-93ER81530
Amount: $600,000

Robots are becoming increasingly important throughout the nuclear industry. They are commonly used to improve operations and maintenance, lower operating costs, enhance worker safety, and reduce radiation exposure to workers. However, the capabilities of existing robots are limited by the systems used to sense their surroundings. Although existing robots often have visual imaging systems and nuclear survey instruments, these sensors do not allow the robot or the operator to easily visualize the distribution of radioactivity around the robot. Time-consuming scanning procedures are required to locate and quantify sources of radioactivity in tasks such as surveillance and inspection of nuclear plants, cleanup operations, and routine processing of nuclear materials. A very compact camera system which will generate a real-time image of the nuclear radiation in the camera's field of view is planned. The resulting image, which can be superimposed on a visual image, will allow the operator to quickly and easily identify the location of sources of nuclear radiation and to measure the intensity of the radiation. Such a capability will be immediately beneficial for robotic and telerobotic operations in nuclear environments. In Phase I, a prototype of such an instrument was developed and was used to image isotopic sources with energies between 0.1 and 1.5 MeV. At 1 MeV, an angular resolution of 5° and an absolute efficiency of $2.1 \mathrm{x} 10^{-6}$ at 1 meter were measured. Based on the Phase I experimental data and on theoretical analyses, it was anticipated that an angular resolution of 6° with an efficiency of $8 \mathrm{x} 10^{-6}$ could be achieved, operating in radiation fields up to 2 rem/hr. Planned for Phase II is the development and testing of a fully functioning robotic imaging system which may be suitable for many nuclear applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: The capabilities of existing robots are restricted by their limited ability to sense their surroundings. The planned sensor should significantly enhance the ability of robotic and telerobotic systems to quickly and rapidly locate sources of nuclear radiation. Such a sensor would find widespread use in present-day robotic applications. The sensor could also be modified for use as a hand-held radiation imaging device, where it would find widespread use in locating and monitoring radiation any place nuclear radiation is used.

TECHNOLOGY FOR SPACE NUCLEAR PROPULSION AND POWER

61

Multilayer, Quantum Well Layer Film Thermoelectrics--Hi-Z Technology, Inc., 6373 Nancy Ridge Drive, San Diego, CA 92121-2247; (619) 535-9343
Mr. Norbert B. Elsner, Principal Investigator
Mr. Norbert B. Elsner, Business Official
DOE Grant No. DE-FG03-93ER81574
Amount: $600,000

Quantum wells, which result from interfacial electronic interactions and are localized within approximately 20 Å of an interface, can alter the electronic properties of materials. These wells may or may not impart beneficial electronic properties to an ensemble of such interfaces. Where the electronic properties of the wells are better than the bulk, it is anticipated that measured electronic properties of a layer ensemble will exceed those of conventional (well free) bulk material. Multilayer Quantum Well Films (ML-QWFs) were investigated as candidate thermoelectric materials because they were predicted, under the condition of highly beneficial wells, to exhibit a sharp gain in the figure of merit (Z) as the quantum bulk material between wells was decreased. This potential gain in Z can be translated into a large increase in conversion efficiency. The experimental results obtained on various ML-QWFs showed that large gains in Z values compared to bulk materials can probably be achieved and that this ultra thin film technology should definitely be pursued. Techniques for preparing these films, such as high rate magnetron sputtering or molecular beam epitaxy (MBE), yielded encouraging results. Because these films remained on their respective substrates, the estimation of their thermoelectric properties required that the properties of the substrate be subtracted from the measured values. In Phase II, thicker (stand-alone) ML-QWFs will be fabricated and measured to verify the results estimated from these initial samples.

Anticipated Results / Potential Commercial Applications as described by the awardee: It should be possible to deposit the required thicker films with existing computer controlled systems. Based on the initial evaluation of these ML-QWFs, it should be possible to commercially fabricate thermoelectric generators that are much more efficient and have lower costs per watt. In addition, it may be possible to fabricate thermoelectric coolers that can achieve lower temperatures and require less power than present thermoelectric units.

62

A High Repetition-Rate, High Power, All-Solid-State Pulsed Driver for Electrodeless Inductive Thrusters--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143; (617) 547-1122
Dr. Xing Chen, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-93ER81532
Amount: $599,937

The objective of this project is the development of long-lived, high-power, high-impulse thrusters for nuclear electronic propulsion. Potential advantages of pulsed electrodeless inductive thrusters over other types of electric thrusters include ultra-low thruster erosion rate resulting in long lifetime, and the ability to operate at very high power levels. The performance of present inductive thrusters has been hindered by the unavailability of reliable, efficient pulsed-power technology. An all-solid-state pulsed driver is being developed that will have greater than 10^{11} shot life and can operate at repetition rates of 1 kilohertz or higher. Benefits derived from these all-solid-state pulsed drivers include higher power capability, lower specific mass, longer lifetime, and increased energy efficiency. In Phase I, detailed analyses of the power and efficiency scaling of an inductive thruster system were conducted. A 40 cm thruster system was designed to be powered with two matched, 100 joule per pulse drivers. These drivers were optimized for generating the pulsed waveforms required for rapid gas breakdown, efficient plasma acceleration, and recovery of the reflected electrical energy. Analysis showed that significant thruster performance improvements can be achieved with these new all-solid-state drivers: total impulse of 10^8 to 10^9 ns is projected compared to 10^6 ns for conventional electric thrusters, with the thruster specific mass reduced to 0.5 kg/kW. The objectives of Phase II are to fabricate the all-solid-state drivers and the thruster system and experimentally demonstrate the thruster technology. The thruster should operate at specific impulses greater than 3000 s with an energy efficiency of greater than 30%.

Anticipated Results / Potential Commercial Applications as described by the awardee: The electrodeless thruster should have the lifetime and total impulse required for a wide range of space missions. The high-power all-solid-state thrusters should increase the total impulse by a factor of 100 to 1000 over conventional electric thrusters. Successful development of this technology could reduce satellite launching cost by up to 25%, resulting in substantial savings for the federal government and the private sector. This contaminant-free plasma acceleration should also be valuable for industrial plasma processes such as microcircuits fabrication.

ENRICHMENT OF URANIUM FOR CIVILIAN POWER REACTORS

63

A Thermally Stable Polypropylene Hybrid Film for Electrical and Packaging Applications--Sigma Labs, Inc., 10960 North Stallard Place, Tucson, AZ 85737; (602) 575-8013
Dr. Angelo Yializis, Principal Investigator
Dr. Angelo Yializis, Business Official
DOE Grant No. DE-FG03-93ER81564
Amount: $600,000

Performance limitations in a bank of commercial polypropylene (PP) capacitors, used in a copper laser invertor by the DOE U-AVLIS group, created an opportunity to investigate an improved capacitor film with superior electrical and thermal properties. An acrylate-PP hybrid film was developed using a patented, high speed, vacuum polymer deposition process, capable of forming thin, uniform, high temperature, electron beam cross-linked acrylate polymers on PP films. Over 100 acrylate polymers were investigated, and full size capacitors were designed and built for the U-AVLIS application, conventional fluorescent ballasts, and energy saving electronic fluorescent ballasts. Electrical and environmental tests of the acrylate-PP and commercial capacitors showed that the hybrid film parts have exceptional overvoltage and current carrying performance, significantly lower electrode corrosion, and an order of magnitude longer life in the presence of intense corona discharges. Capacitors designed to serve the copper laser inverter were far superior in high voltage, high dV/dt tests to equal size commercial units. Phase II will involve scale-up of the acrylate-PP film production equipment, optimization of the acrylate-PP hybrid films for specific applications, production of a capacitor bank for the copper laser inverter, and two additional capacitor designs for commercial applications. Short and long term accelerated life tests will be conducted to investigate failure mechanisms and product reliability. A product plan will be developed to address the production of capacitors, capacitor materials, and other potential applications for the acrylate hybrid films. By the end of Phase II, pilot facilities should be in place for the production of acrylate hybrid films and metallized capacitors.

Anticipated Results/Potential Commercial Applications as described by the awardee: This work should lead to the development and production of a new hybrid polypropylene film that has a broad range of applications, including electrical and electronic capacitors, and high oxygen and moisture barrier film for food packaging. Metallized capacitors produced with the hybrid film should have superior current carrying characteristics and higher energy density than commercially available products. The potential of adding functional value to existing films for relatively low costs, should create several opportunities for the acrylate hybrid films in both electrical and packaging applications. In food packaging applications, the shelf life of snack foods packaged using the high barrier hybrid film is estimated to double, resulting in significant savings and a strong competitive advantage over imported products.

APPENDIX A

Alphabetical List of Awardees

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Dr. David G. Hamblen, Business Official 34
Dr. Peter R. Solomon, Business Official ... 3, 20, 38
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Advanced Refractory Technologies, Inc. *29*
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Advanced Resources International, Inc. *13*
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American Superconductor Corporation *30*
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Ashwin-Ushas Corporation, Inc. *22*
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BioTraces, Inc. *39*
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Chemat Technology, Inc. *31*
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Composite Technology Development, Inc. *50*
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Creare, Inc
Mr. Robert A. Hickin, Business Official ... *42*
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DULY Research, Inc. *43*
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Energy and Environmental Research Corporation *36*
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References denote entry numbers

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Northwest Fuel Development, Inc. ***15***
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Omega-P, Inc. ***48***
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Videodiscovery, Inc. ***27***
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(610) 489-2255

APPENDIX B

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DEPARTMENT OF ENERGY

SBIR

1995

PHASE I AND

PHASE II

AWARDS

SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM
(SECOND PROGRAM SOLICITATION FOR FISCAL YEAR 1993, ANNOUNCEMENT DOE/ER-0582)

U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585
November 28, 1994

SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM
(SECOND PROGRAM SOLICITATION FOR FISCAL YEAR 1993, ANNOUNCEMENT DOE/ER-0582)

As a former chairman of the SBIR Application Score Verification Panel that had been appointed to evaluate Phase II grant applications for the SBIR program, I am familiar with the Panel's evaluation procedures and its methodology. I believe that the Panel has proceeded in accordance with applicable laws and regulations, that the evaluation was thorough and equitable, and that the information presented formed a sound basis for selection. This statement describes the procurement and sets forth my selection decision.

Procurement Description

The Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564), requires that each Federal agency with an extramural research or research and development budget exceeding $100 million establish an SBIR program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies over the 18 years of the program are as follows:

Fiscal Year	SBIR Set Aside (%)
1983	0.2
1984	0.6
1985	1.0
1986-1992	1.25
1993-1994	1.5
1995-1996	2.0
1997-2000	2.5

Public Law 102-564 also required, for the first time, the participation in the DOE SBIR program of the Department's programs in Environmental Management, and Nonproliferation and National Security. The second program solicitation for FY 1993 was issued because of this law and contained eight technical topics from these program areas.

Public Laws 97-219 and 102-564 also prescribe that the SBIR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the SBIR program. This phase will have a period of performance which is typically six months in duration. Awards during this phase will be up to $75,000. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $600,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-

Federal capital and may also involve follow-on, non-SBIR funded Federal contracts for products or services intended for use by the U.S. Government.

On April 15, 1993, the Department of Energy (DOE) issued a second solicitation for fiscal year 1993 for Phase I SBIR grant applications. We received 509 applications in response to that solicitation; and on October 22, 1993, we selected 33 applications for Phase I funding, of which 32 proceeded to grants on December 28, 1993.

The Phase II SBIR program competition is limited to successful Phase I awardees. Under DOE procedures, grant applications for Phase II could be submitted at any time when it was deemed that sufficient progress had been attained under Phase I to justify the effort to be proposed for further development under Phase II. Applicants who wanted to maintain project funding continuity from Phase I to Phase II were asked by DOE to submit their applications not later than May 23, 1994, whereas the submission deadline for proposers not seeking to preserve project continuity was September 12, 1994. Based on the 32 Phase I awards, 8 Phase II applications were submitted by the May 23, 1994, deadline. From this submission, two were selected for Phase II awards in July 1994.

This current selection is made from applicants not seeking to preserve project continuity and from those applications that were received by May 23, 1994, but not yet funded. Of the group, 19 were received by the September 12, 1994 deadline, and 6 were not funded from the earlier submissions, for a total of 25 applications eligible for funding at this time.

Selection Criteria

Selections for Phase II awards were made on scientific and technical merit and commercial potential based upon the criteria listed below. Criterion 1 is given twice the weight of each of the other criteria. The six criteria are as follows:

1. The scientific/technical quality of the proposed research or R&D with special emphasis on its degree of innovation.

2. The qualifications of the Principal Investigator and other key personnel to carry out the proposed work and the level of adequacy of available or obtainable instrumentation and facilities.

3. The anticipated benefits, technical and/or economic, of the proposed research, with special emphasis on the likelihood that the project will attract further funding for product or process development after the SBIR support expires.

4. The degree to which the Phase I objectives were met at the time of Phase II grant application submission.

5. The soundness and level of adequacy of the Phase II proposed work plan to meet the problem or opportunity.

6. The commercial potential of the proposed research or R&D as evidenced by (a) the small business concern's record of commercializing SBIR or other research, (b) the existence of Phase II funding commitments from private sector or non-SBIR funding sources, (c) the existence of Phase III follow-on funding commitments for the subject of the research, and (d) the presence of other indicators of commercial potential of the idea.

Criteria 1 through 5 ensure that award decisions will be based primarily on scientific and technical merit. Criterion 6 on commercial potential is new this year and was added to conform to the requirements of P.L. 102-564.

In all applications selected for awards, it was demonstrated that a minimum of one-half of the funded research or analytical effort would be performed by the applicant organization.

Selection Rationale

A Technical Project Manager (TPM) was appointed for each of the Phase I projects resulting from successful Phase I applications. Expert reviewers including DOE Laboratory personnel, university professors, and private industry personnel were selected with the help of the TPM, and they evaluated applications against criteria 1 through 5 and 6d. The TPM then scored applications based on these reviews. An SBIR Application Score Verification Panel, consisting of DOE staff and other technical personnel, was established to ensure relative uniformity of scoring across the board for these criteria and to assure that scores were based predominantly on meaningful technical reviews. The Panel was also chartered to ensure that there was consistency of scoring both within and between topics.

Criteria 6a, 6b, and 6c were evaluated by Panel members based on (non-technical) information provided in the grant applications, and a score was assigned for each of these criteria. The scores for 6a, 6b, 6c, and 6d were combined, with equal weight for each, to arrive at a single score for criterion 6. Then each application was assigned a total score based on the weighting described in the beginning of the previous section. Finally, the Panel ranked the 25 applications in order of their total scores.

I have looked at the evaluation documentation presented by the TPMs. I have also carefully reviewed the recommendations of the SBIR Application Score Verification Panel and have agreed that the evaluations of the reviewers, the scoring of the TPMs, and the recommendations of the Panel provided valid bases upon which to make a selection. Therefore, based on the ranking of the Panel, I have selected 7 applications for negotiation for award. This brings the total number of Phase II applications selected for negotiation to 9 including the 2 selections made in July 1994. Included in the 9 applications are all those which were within four points of the highest possible total score. It is my view that the applications selected for negotiation represent outstanding technical quality and attest to the commitment of the SBIR program to excellence and to the development of high technology in the small business sector.

Samuel J. Barish

Samuel J. Barish
SBIR Program Manager
Date: 11/28/94

Attachments:
Appendix A: Listing of applications selected for negotiation for award.
Appendix B: Project summary of each application.

Appendix A

DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1995 PHASE II AWARDS
SECOND FY 1993 SOLICITATION

Company	Project Title
Advanced Technology Materials, Inc. 7 Commerce Drive Danbury, CT 06810	A Micro Pyrovidicon: An Infrared Imaging Device for Intrusion Detection
Andcare, Inc. 2810 Meridian Parkway Suite 152 Durham, NC 27713	Innovative Electrochemical Sensors for In-Situ, Real-Time Monitoring of Lead in Aqueous Media
Atlantic Aerospace Electronics Corporation 470 Totten Pond Road Waltham, MA 02154	Automated Identification of Man-Made Objects via Multi-Spectral Image Exploitation
Optiphase, Inc. 7652 Haskell Avenue Van Nuys, CA 91406-2005	An Intelligent Intrusion Detection System Using a Fiber Optic Sensing Network
Physical Optics Corporation 2545 West 237th Street, Suite B Torrance, CA 90505	A Highly Versatile Tunable Multi-Spectral Imaging Sensor Based on a Micro Spectrographic Array Filter Concept
Physical Optics Corporation 2545 West 237th Street, Suite B Torrance, CA 90505	Multimode Sensor Network Media
*RAND Technologies Corporation 9461-B Silver King Court Fairfax, VA 22031	An Automated Radio Frequency Tagging Method for Tamper Protected Inventory Control of Special Nuclear Material Containers
*Stange Associates 5853 Finecrest Crest Rancho Palos Verdes, CA 90274	A Document Imaging, Indexing, and Retrieval System for International Atomic Energy Agency Special Inspections
Xsirius, Inc. 1220 Avenida Acaso Camarillo, CA 93012	An Ultra-Compact Cesium Iodide/Mercuric Iodide Gamma-Ray Scintillation Spectrometer

*Project provided with funding continuity following application submission by May 23, 1994.

Advanced Technology Materials, Inc.
7 Commerce Drive
Danbury, CT 06810

A Micro Pyrovidicon: An Infrared Imaging Device for Intrusion Dectection

Thermal imaging is enlarging its scope from military surveillance and night vision to include process monitoring, control, predictive maintenance, automotive sensors, and even home air conditioner controls. Phase I demonstrated a novel compact infrared (IR) imaging detector, the micropyrovidicon, which contrasts favorably with currently available systems. The micropyrovidicon provides high resolution, small size, low weight, low power consumption, high reliability, and room temperature operation. In addition, it is inexpensive to manufacture and can be made compatible with existing IR intrusion detection systems. The micropyrovidicon, which uses a pyroelectric sensing element and a compact electron beam signal detection and read-out sub-system, is fabricated using proven semiconductor fabrication techniques. The low costs of volume semiconductor manufacturing make the micropyrovidicon-based array an attractive alternative for commercial and military detection systems. The planned detection system is based on a micropyrovidicon vacuum tube array fabricated using micro-machining techniques. Phase I demonstrated the feasibility of fabricating a single pixel micropyrovidicon device and the use of a miniature cold cathode electron source to detect an IR induced image on a pyroelectric element with a temperature resolution of 0.08°C/nA. Phase II will develop a base-line manufacturing process to integrate the pyroelectric detection array with the cold cathode array for signal detection and read-out. A prototype two dimensional 40 x 40 array micropyrovidicon detector will be delivered.

Anticipated Results/Potential Commercial Applications as described by the awardee: A successful Phase II project should produce an inexpensive, light drop-in replacement for an expensive heavy tube. In Phase III the scale-up and manufacture of a large format 512 by 512 micropyrovidicon detector array will be addressed. Lower parts and systems costs should allow proliferation of the technology into industrial, automotive, and domestic applications from intrusion detection to predictive maintenance and process control.

AndCare, Inc.
2810 Meridian Parkway
Suite 152
Durham, NC 27713

Innovative Electrochemical Sensors for In-Situ, Real-Time Monitoring of Lead in Aqueous Media

Post-closure monitoring of environmentally remediated sites requires the monitoring of chemical composition in real time and in situ. Samples of material cannot be removed for subsequent analysis because the chemical components of interest may be unstable or because immediate information on changes in composition may be required. Phase I established the feasibility of an innovative amperometric electrochemical sensor containing colloidal gold particles to facilitate continuous, in-situ, real-time monitoring of lead in ground water and other aqueous media. The method consists of applying a negative potential to reduce the Pb^{++} to elemental lead on the colloidal gold surface, and then applying a positive potential to strip off the deposited lead. In Phase II, key parameters of the electrochemical sensor's formulation and operation will be optimized in order to develop an initial prototype of a commercial product. The anticipated result is a novel stripping electrochemical sensor to continuously monitor lead in in-situ conditions. The technology will lower production costs of electrochemical sensor production and increase sensor performance, resulting in a reduction of environmental remediation costs.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated results are low-cost, colloidal gold coated electrochemical sensors for real-time, in-situ, post-closure monitoring of lead, cadmium, mercury and other heavy metals in groundwater and other aqueous media. Specific groups that should use the results include DOE, Superfund clean-up firms, and smaller environmental remediation companies.

Atlantic Aerospace Electronics Corporation
470 Totten Road
Waltham, MA 02154

Automated Identification of Man-Made Objects via Multi-Spectral Image Exploitation

The task of identifying arms control and nonproliferation violations from remotely sensed data requires the ability to distinguish image features based on very subtle cues. This has resulted in labor-intensive, manual processes, and there are not enough analysts to go through the large quantity of data collected. A fractal-based processing system which can respond to subtle differences in image texture is planned for the detection and discrimination of man-made objects embedded in the natural clutter. The system enables a photo interpreter to quickly screen the enormous amount of imagery currently being collected and offers major performance improvements with significantly less hardware needed for real-time implementation than current state-of-the-art techniques. Phase I developed procedures that automatically direct a human analyst to image regions consisting of man-made structures. In Phase II, the initial cueing capabilities will be extended to include object identification and the indication of structural changes. Final decisions on the occurrence of violations will be made by human photo interpreters; however the automated procedures developed will increase their productivity.

Anticipated Results/Potential Commercial Applications as described by the awardee: The algorithms developed in Phases I and II will be integrated into a software package and marketed as an application upgrade for analyst workstations. The targeted application base should span a number of diverse application areas, including arms control and proliferation verification, military reconnaissance and surveillance, and intelligence. In addition, the technology developed under this effort has commercial applications including drug interdiction (surveillance), nondestructive evaluation (defect detection), and biomedical image applications.

Optiphase, Inc.
7652 Haskell Avenue
Van Nuys, CA 91406-2005

An Intelligent Intrusion Detection System Using a Fiber Optic Sensing Network

Conventional intrusion detection systems which monitor large secure areas often generate false and "nuisance" alarms at rates well in excess of one per month (an objective for the security industry). The causes of these false and nuisance alarms include rapid air temperature and pressure variations, precipitation, seismic activity from nearby traffic, electromagnetic interference (EMI), and sensor self noise. Efforts to reduce error rates using smart processing of the sensor information have resulted in little or no improvement. This is because conventional intrusion detection approaches use non-linear sensing techniques which are oriented towards detecting events rather than accurately measuring them. The objective of Phase I was to investigate and demonstrate a fiber optic interferometric sensing approach which accurately measures intrusion-type events with high resolution, so that signal processing could effectively discriminate between true, false, and nuisance alarms. In Phase

I, a 40 square foot distributed fiber sensor and analog electronic processor were developed and field tested with the following results: 100% intrusion alarming for an 80+ pound intruder; 0 false alarms and 0 nuisance alarms. In Phase II, a full scale intelligent intrusion detection system, providing coverage for a 100 meter long security zone, will be developed and field tested. Additionally, an intelligent digital processor will be developed to be used in conjunction with the fiber optic sensing approach. The objective is to identify events experienced by the zone deployed sensor so that "intruders" are detected with 100% probability, nuisance events are identified, and false alarm rates are less than one per month.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned fiber optic sensing approach should address an unlimited number of commercial security and safety applications, where low price, ease of deployment, high accuracy and immunity to EMI are required. Commercial industrial coverage includes: intrusion detection, perimeter protection, and physical plant safety monitoring. This technology, given the proper price to volume ratios, could also extend to home security and safety applications.

Physical Optics Corporation
2545 West 237th Street
Suite B
Torrance, CA 90505

A Highly Versatile Tunable Multi-Spectral Imaging Sensor Based on Micro Spectrographic Array Filter Concept

This project will develop a unique nanotechnology for Cascaded Array Multispectral Imaging Sensors (CAMIS) that can provide real-time, spectrally tunable operation with unique spectral processing capabilities and no moving parts. These sensors are based on the unique integration of micro-optics, holographic components, high-speed spatial-light-modulators, and charge coupled detector arrays. They will provide simultaneous target location and identification in real-time and with high accuracy. Phase I demonstrated that the CAMIS concept not only is feasible, but also provides strong advantages over existing techniques. It was also demonstrated that all of the basic components of the system can be fabricated and integrated in a cost effective manner. Phase II will further develop this nanotechnology and integrate it into a full prototype CAMIS system. The unique nanotechnology integration, combined with a novel system design, should produce a key breakthrough in multispectral imaging, resulting in a CAMIS system wich is extremely compact, lightweight, highly rugged, and very cost effective. It will also be versatile and integratable with the existing signal processing systems, including current satellite imaging systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: This

CAMIS technology should provide a new generation of highly versatile, low cost multispectral imaging sensors for remote sensing applications. This technology should also can find many applications in biomedical spectroscopic imaging, laser radar, and optical communications.

Physical Optics Corporation
2545 West 237th Street
Suite B
Torrance, CA 90505

Multimode Sensor Network Media

The simultaneous real-time monitoring and control of a large number of distributed sensors is required for DOE's waste management and clean-up applications. This project addresses a new sensor data management system based on an innovative fiber optic Multimode Sensor Network Media (MSNM) architecture, using the latest advances in wavelength division multiplexing and holography. Phase I demonstrated that this optically mixed (analog/digital) multiplexing technology can provide high bandwidth parallel data processing from 1000 sensors with extremely fast random access time. The MSNM approach can offer exceptionally high power budgets and provide highly distributed long distance (40 km x 40 km) transmission of parallel signals over a single fiber. In addition, the MSNM architecture can provide full interoperability among different network standards. This greatly simplifies the management of diversified data that simultaneously arrive from sensors, characterization/remediation devices, and data processors. In Phase II, remote MSNM modules will be designed, developed, and tested. The entire MSNM system will be highly rugged, radiation hard, insensitive to electromagnetic interference, and very cost effective.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned MSNM systems should provide a series of totally new real-time sensor, monitoring and control network modules for DOE's waste management and clean-up applications. These products should also have a very strong commercial potential for use in multimedia communication networks, the National Information Infrastructure (NII), and for industrial process control.

Rand Technologies Corporation
9461 Silver King Court
Fairfax, VA 22031

An Automated Radio Frequency Tagging Method for Tamper Protected Inventory Control of Special Nuclear Material Containers

DOE is responsible for the long term storage and protection of large quantities of special nuclear material (SNM). This material is stored within individual containers located in vaults at a number of widely scattered sites throughout the country. Special security and inventory measures are required to ensure that the SNM remains within the containers where it is stored and that it is not disturbed in any manner. Conventional security and inventory techniques are manpower intensive and often require exposure to radiation hazards. Studies show that automation of the SNM monitoring function would improve the level of security, reduce radiation exposure to DOE personnel connected with conducting physical inventories, and reduce real costs of maintaining inventory control of SNM. Based on literature research, site visits, and extensive discussions with key individuals at DOE and several National Laboratories, a detailed system specification was completed and published. This document formed the basis for the design of a prototype system. The design approach is based on a radio frequency tag polling concept that permits the rapid polling of small tags attached to individual SNM containers. The design incorporates a highly effective tamper indicating device (TID) which detects changes in the weight of the container. In addition there is a provision for the transmission of data from other sensors (e.g., radiation signature) that may be added to the system in the future. The battery powered tags will be highly reliable so that reentry into a vault for tag or battery replacement is minimal. Key elements of this system have been fabricated and tested in order to demonstrate the feasibility of this approach. The results of initial testing confirm that the specifications can be met in an affordable and practical package. The Phase II project will design and fabricate a full function prototype system to include the development of specialized integrated circuits. This prototype will be tested using an actual, currently unused vault to best simulate realistic conditions.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will demonstrate a full capability prototype system for SNM inventory monitoring using the tag polling design. This system should meet all of DOE's performance requirements at an affordable price, and, when fielded, should repay its cost rapidly through reduced requirements for manual SNM inventory inspections. The hardware and software being developed for this project should have numerous commercial applications in such areas as high value item inventory management, material and personnel tracking, transportation (toll collection, remote truck weighing, etc.), and many others.

Stange Associates
5853 Finecrest Drive
Rancho Palos Verdes, CA 90274

A Document Imaging, Indexing, and Retrieval System for International Atomic Energy Agency Special Inspections

Much progress has been made in recent years in digitizing information. Dictionaries, encyclopedias, books, maps, movies and periodicals on CD-ROMs are commonplace. Companies have also learned how to scan documents into an image file so that paper transactions can take place electronically. Nevertheless, much progress remains to be made in terms of adapting imaging systems to particular work environments, especially regarding the search and retrieval of information relevant to a user's need. This project explores a method to scan documents--text, drawings, maps, and photos--which permits information to be retrieved by a single search of all data, regardless of its original form. Designated objects on photos and drawings will be indexed and retrievable, and maps and photos of a geographic nature will be indexed geographically so that they may also be retrieved based on location and not necessarily on explicit content. Additionally, it is planned to develop: (1) a method for desktop computer users to submit documents for inclusion in the document data base, (2) a field system to allow data collection as well as search and retrieval at a remote site, and (3) a method of extracting a portion of the master data base and sending it to the field for use by remote or isolated users. Phase II will focus on four products: a high volume processing system for converting current paper files to electronic format, desktop systems for including newly received and produced documents in the document database, field systems for collecting document data from remote or isolated locations, and the central document handling system. This product orientation emphasizes production and delivery of an integrated system and not simply a collection of components. Cost reduction and future technology planning are written into each of the tasks, assuring the lowest cost, highest performance system possible. The project should result in a complete system, operations procedures, training requirements, system performance data, and key technology areas where particularly high leverage changes are taking place.

Anticipated Results/Potential Commercial Applications as described by the awardee: Billions of dollars have been spent in collecting information on nuclear weapons programs around the world, yet much of it is stored in hard copy making it difficult to analyze. The planned system can change that situation for the International Atomic Energy Agency and DOE. To be sure, applications of this technology are very wide: research into innovative searching and retrieval schemes extends even into such non-traditional fields as music publishing.

Xsirius, Inc.
1220 Avenida Acaso
Camarillo, CA 93012

An Ultra-Compact Cesium Iodide/Mercuric Iodide Gamma-Ray Scintillation Spectrometer

Ultra-compact hand held units for assaying low-grade radioactive materials are needed for cleanup activities and facility transition. New technology is required to overcome limitations such as inferior energy resolution for photomultiplier tubes (PMTs) and silicon devices; disadvantages such as large size, voltage regulation, and magnetic field sensitivity of PMTs; and the bulky apparatus associated with cryogenic cooling for direct gamma detectors such as germanium. This project will couple large mercuric iodide (HgI_2) photodetectors to highly optimized cesium iodide (thallium) [CsI(Tl)] scintillators in order to increase the energy resolution and decrease the size and weight of detector systems. Phase I confirmed the feasibility of growing high quality HgI_2 crystalline material and fabricating large-area photodetectors with diameters up to one inch. Scintillator/photodetector pairs and new optimized electronics were constructed and evaluated. Phase II will build and test a prototype demonstration detector instrument exhibiting energy resolution of 5% or better for 662 keV gamma rays. The instrument will contain a primary detector composed of novel tapered CsI(Tl) scintillator optically coupled to one or more HgI_2 photodetectors. The dimensions of the primary detector will provide similar gamma-collection efficiency to a standard 2 inch by 3 inch NaI detector. The system will employ low noise electronics and will be packaged in a rugged fieldable format.

Anticipated Results/Potential Commercial Applications as described by the awardee: The instrument design features which will be developed should have application to many gamma ray spectroscopy and monitoring applications. The particular advantages (small size, high detection efficiency, superior ruggedness, and good energy resolution) of the HgI_2 based system for gamma detection can be used in instrumentation throughout the gamma ray spectroscopy community and should find widespread use in space instruments, high energy physics research, health physics, personnel monitoring, medical research, and other commercial applications.

DOE/ER-0637

Small Business Innovation Research

ABSTRACTS OF PHASE II AWARDS

1995

(FROM SECOND 1993 SOLICITATION)

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager

DOE/ER-0637

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE II AWARDS

1995

(FROM SECOND 1993 SOLICITATION)

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager

PREFACE

The SBIR program enables DOE to obtain effective, innovative solutions to important problems through the private sector, which has a commercial incentive to pursue the resulting technology and bring it to the marketplace. The growing number of awardees, many of them started in business in response to SBIR solicitations, is becoming a significant resource for the solution of high risk, high technology problems for the Department. As detailed below, this publication describes the technical efforts and commercialization possibilities for those SBIR Phase II awards made in 1994 and 1995 in response to the second Fiscal Year (FY) 1993 solicitation. It is intended for the educated layman, and may be of particular interest to potential investors who wish to get in on the ground floor of exciting opportunities.

The Federal SBIR Program

This program, now completing its thirteenth year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Eleven Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over $100 million. The agencies are required to set aside 2.0% of those budgets in FY 1995 to fund SBIR projects. (This amounts to about $70 million in FY 1995 for the Department of Energy.) Each agency solicits proposals from small science- and technology-based US firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to $75,000 in FY 1993. Phase II is the principal research or R&D effort, and the awards were as high as $600,000 in FY 1994 for work to be performed in a period of up to two years. Phase III is the commercial application of the research or R&D effort by the small businesses using non-Federal funding or, alternatively, it may involve follow-on non-SBIR Federal contracts for products or services desired by the Government. The program continues to strengthen the role that small, innovative firms play in meeting the Nation's research and development needs and in commercialization of ideas developed through federally funded R&D.

Phase II Awards for FYs 1994 and 1995

Contained in this booklet are abstracts of the Phase II awards made in FYs 1994 and 1995 under the DOE SBIR program in response to the second FY 1993 solicitation.

DOE received 509 grant applications to this solicitation, and on October 22, 1993, 32 were selected for Phase I funding.

Applicants desiring to maintain project funding continuity from Phase I to Phase II were invited to submit their grant applications to DOE not later than May 23, 1994, approximately 6 weeks before the end of their Phase I grants. Eight Phase II applications were submitted by that date, and 2 were selected for Phase II awards; those projects were then able to continue without funding interruption between Phases I and II. The deadline for the submission of Phase II applications for applicants not seeking to maintain project funding continuity was September 12, 1994. From the 19 applications submitted by this date and from the 6 unfunded applications from the May 23, 1994, submissions, 7 were selected for Phase II awards. The 9 Phase II projects described in this book consist of these 7 projects and the 2 projects that were funded from the May 23 submissions. The listed amount of each award, in many instances, is subject to completion of award negotiations.

The DOE SBIR Program

DOE's second FY 1993 annual Solicitation contained 8 technical topics in the areas of environmental management, arms control and nonproliferation, and security affairs. There is keen competition because awards are made solely on the basis of scientific and technical merit, regardless of the technical topic.

As a measure of the program's success, eleven DOE SBIR projects have received R&D-100 Awards from Research and Development Magazine, which selects the 100 most significant technical products each year. In addition, five DOE awardees were chosen among the 500 fastest-growing American private companies, in the December 1991 issue of Inc. Magazine, based on their growth in sales. Also, from the first six cycles of awards (Phase II projects completed between 1986 and 1991), DOE SBIR winners have already received approximately $260 million in Phase III funding, which is about 60% larger than the SBIR support they were given. This number is expected to grow significantly in the next few years.

The DOE SBIR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. In the first year of Phase II awards (1984), a system was devised and implemented that allowed Phase I awardees who felt they were ready to submit their Phase II applications before their Phase I grants ended, to do so. For each of the eleven years in which Phase II awards have been made, such grantees who were chosen for Phase II funding were able to begin their projects without an interruption in funding. Since 1984, about 40% of the Phase II awardees have had continuous funding between Phases I and II.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, DOE has instituted a special training project, supported by non-SBIR funds. For the past five years, successful Phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participation in the 1991 project, the SBIR companies have already received more than $14 million for commercialization of their SBIR research, with a projected royalty stream from option agreements of an additional $24 million over the next four years. About 43% of the firms that completed the project have received further funding for their work. Sources of capital that wish to consider participation in future programs should contact Dr. Robert Berger, U.S. Department of Energy SBIR Program, ER-16, Washington, D.C. 20585, (301-903-3054).

Samuel J. Barish
SBIR Program Manager
US Department of Energy
Washington, DC 20585

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SENSORS FOR MONITORING ENVIRONMENTAL REMEDIATION ACTIVITIES

1

Innovative Electrochemical Sensors for In-Situ, Real-Time Monitoring of Lead in Aqueous Media--AndCare, Inc., 2810 Meridian Parkway, Suite 152, Durham, NC 27713; (919) 544-8220
Dr. John P. O'Daley, Principal Investigator
Mrs. Camille Blommer, Business Official
DOE Grant No. DE-FG05-94ER81657
Amount: $600,000

Post-closure monitoring of environmentally remediated sites requires the monitoring of chemical composition in real-time and in-situ. Samples of material cannot be removed for subsequent analysis because the chemical components of interest may be unstable or because immediate information on changes in composition may be required. Phase I established the feasibility of an innovative amperometric electrochemical sensor containing colloidal gold particles to facilitate continuous, in-situ, real-time monitoring of lead in groundwater and other aqueous media. The method consists of applying a negative potential to reduce the Pb^{++} to elemental lead on the colloidal gold surface, and then applying a positive potential to strip off the deposited lead. In Phase II, key parameters of the electrochemical sensor's formulation and operation will be optimized in order to develop an initial prototype of a commercial product. The anticipated result is a novel stripping electrochemical sensor to continuously monitor lead in in-situ conditions. The technology will lower production costs of electrochemical sensor production and increase sensor performance, resulting in a reduction of environmental remediation costs.

Anticipated Results / Potential Commercial Applications as described by the awardee: The anticipated results are low-cost, colloidal gold coated electrochemical sensors for real-time, in-situ, post-closure monitoring of lead, cadmium, mercury and other heavy metals in groundwater and other aqueous media. Specific groups that should use the results include DOE, Superfund clean-up firms, and smaller environmental remediation companies.

WASTE STREAM DIAGNOSTICS AND CONTROLS

2

Multimode Sensor Network Media--Physical Optics Corporation, 20600 Grammercy Place, Suite 103, Torrence, CA 90501; (310) 320-3088
Dr. Vladimir Katsman, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-94ER81676
Amount: $599,983

The simultaneous real-time monitoring and control of a large number of distributed sensors is required for DOE's waste management and clean-up applications. This project addresses a new sensor data management system based on an innovative fiber optic Multimode Sensor Network Media (MSNM) architecture, using the latest advances in wavelength division multiplexing and holography. Phase I demonstrated that this optically mixed (analog/digital) multiplexing technology can provide high bandwidth parallel data processing from 1000 sensors with extremely fast random access time. The MSNM approach can offer exceptionally high power budgets and provide highly distributed long distance (40 km x 40 km) transmission of parallel signals over a single fiber. In addition, the MSNM architecture can provide full interoperability among different network standards. This greatly simplifies the management of diversified data that simultaneously arrive from sensors, characterization/remediation devices, and data processors. In Phase II, remote MSNM modules will be designed, developed, and tested. The entire MSNM system will be highly rugged, radiation hard, insensitive to electromagnetic interference, and very cost effective.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned MSNM systems should provide a series of totally new real-time sensor, monitoring and control network modules for DOE's waste management and clean-up applications. These products should also have a very strong commercial potential for use in multimedia communication networks, the National Information Infrastructure (NII), and for industrial process control.

ARMS CONTROL AND NONPROLIFERATION VERIFICATION AND DETECTION TECHNOLOGY

3

Automated Identification of Man-Made Objects via Multi-Spectral Image Exploitation--Atlantic Aerospace Electronics Corporation, 470 Totten Pond Road, Waltham, MA 02154; (617) 890-4200
Ms. Tamar Peli, Principal Investigator
Dr. Theodore Bially, Business Official
DOE Grant No. DE-FG02-94ER81658
Amount: $599,683

The task of identifying arms control and nonproliferation violations from remotely sensed data requires the ability to distinguish image features based on very subtle cues. This has resulted in labor-intensive, manual processes, and there are not enough analysts to go through the large quantity of data collected. A fractal-based processing system which can respond to subtle differences in image texture is planned for the detection and discrimination of man-made objects embedded in the natural clutter. The system enables a photo interpreter to quickly screen the enormous amount of imagery currently being collected and offers major performance improvements with significantly less hardware needed for real-time implementation than current state-of-the-art techniques. Phase I developed procedures that automatically direct a human analyst to image regions consisting of man-made structures. In Phase II, the initial cueing capabilities will be extended to include object identification and the indication of structural changes. Final decisions on the occurrence of violations will be made by human photo interpreters; however the automated procedures developed will increase their productivity.

Anticipated Results / Potential Commercial Applications as described by the awardee: The algorithms developed in Phases I and II will be integrated into a software package and marketed as an application upgrade for analyst workstations. The targeted application base should span a number of diverse application areas, including arms control and proliferation verification, military reconnaissance and surveillance, and intelligence. In addition, the technology developed under this effort has commercial applications including drug interdiction (surveillance), nondestructive evaluation (defect detection), and biomedical image applications.

4

A Highly Versatile Tunable Multi-Spectral Imaging Sensor Based on a Micro Spectrographic Array Filter Concept--Physical Optics Corporation, 20600 Grammercy Place, Suite 103, Torrance, CA 90501; (310) 320-3088
Dr. Tin M. Aye, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-94ER81677
Amount: $599,978

This project will develop a unique nanotechnology for Cascaded Array Multispectral Imaging Sensors (CAMIS) that can provide real-time, spectrally tunable operation with unique spectral processing capabilities and no moving parts. These sensors are based on the unique integration of micro-optics, holographic components, high-speed spatial-light-modulators, and charge coupled detector arrays. They will provide simultaneous target location and identification in real-time and with high accuracy. Phase I demonstrated that the CAMIS concept not only is feasible, but also provides strong advantages over existing techniques. It was also demonstrated that all of the basic components of the system can be fabricated and integrated in a cost effective manner. Phase II will further develop this nanotechnology and integrate it into a full prototype CAMIS system. The unique nanotechnology integration, combined with a novel system design, should produce a key breakthrough in multispectral imaging, resulting in a CAMIS system which is extremely compact, lightweight, highly rugged, and very cost effective. It will also be versatile and integratable with the existing signal processing systems, including current satellite imaging systems.

Anticipated Results / Potential Commercial Applications as described by the awardee: This CAMIS technology should provide a new generation of highly versatile, low cost multispectral imaging sensors for remote sensing applications. This technology should also can find many applications in biomedical spectroscopic imaging, laser radar, and optical communications.

INTERNATIONAL ATOMIC ENERGY AGENCY SPECIAL SAFEGUARDS INSPECTIONS

5

A Document Imaging, Indexing, and Retrieval System for International Atomic Energy Agency Special Inspections--Stange Associates, 5853 Finecrest Drive, Rancho Palos Verdes, CA 90274; (310) 541-9574
Dr. Albert E. Glock, Principal Investigator
Mr. L. G. Stange, Business Official
DOE Grant No. DE-FG03-94ER81683
Amount: $599,923

Much progress has been made in recent years in digitizing information. Dictionaries, encyclopedias, books, maps, movies and periodicals on CD-ROMs are commonplace. Companies have also learned how to scan documents into an image file so that paper transactions can take place electronically. Nevertheless, much progress remains to be made in terms of adapting imaging systems to particular work environments, especially regarding the search and retrieval of information relevant to a user's need. This project explores a method to scan documents--text, drawings, maps, and photos--which permits information to be retrieved by a single search of all data, regardless of its original form. Designated objects on photos and drawings will be indexed and retrievable, and maps and photos of a geographic nature will be indexed geographically so that they may also be retrieved based on location and not necessarily on explicit content. Additionally, it is planned to develop: (1) a method for desktop computer users to submit documents for inclusion in the document data base, (2) a field system to allow data collection as well as search and retrieval at a remote site, and (3) a method of extracting a portion of the master data base and sending it to the field for use by remote or isolated users. Phase II will focus on four products: a high volume processing system for converting current paper files to electronic format, desktop systems for including newly received and produced documents in the document database, field systems for collecting document data from remote or isolated locations, and the central document handling system. This product orientation emphasizes production and delivery of an integrated system and not simply a collection of components. Cost reduction and future technology planning are written into each of the tasks, assuring the lowest cost, highest performance system possible. The project should result in a complete system, operations procedures, training requirements, system performance data, and key technology areas where particularly high leverage changes are taking place.

Anticipated Results / Potential Commercial Applications as described by the awardee: Billions of dollars have been spent in collecting information on nuclear weapons programs around the world, yet much of it is stored in hard copy making it difficult to analyze. The planned system can change that situation for the International Atomic Energy Agency and DOE. To be sure, applications of this technology are very wide: research into innovative searching and retrieval schemes extends even into such non-traditional fields as music publishing.

TECHNOLOGIES FOR DOMESTIC NONPROLIFERATION AND SAFEGUARDS

6

A Micro Pyrovidicon: An Infrared Imaging Device for Intrusion Detection--Advanced Technology Materials, Inc., 7 Commerce Drive, Danbury, CT 06810; (203) 794-1100
Dr. Galina Doubinina, Principal Investigator
Mr. Ward C. Stevens, Business Official
DOE Grant No. DE-FG05-94ER81655
Amount: $600,000

Thermal imaging is enlarging its scope from military surveillance and night vision to include process monitoring, control, predictive maintenance, automotive sensors, and even home air conditioner controls. Phase I demonstrated a novel compact infrared (IR) imaging detector, the micropyrovidicon, which contrasts favorably with currently available systems. The micropyrovidicon provides high resolution, small size, low weight, low power consumption, high reliability, and room temperature operation. In addition, it is inexpensive to manufacture and can be made compatible with existing IR intrusion detection systems. The micropyrovidicon, which uses a pyroelectric sensing element and a compact electron beam signal detection and readout sub-system, is fabricated using proven semiconductor fabrication techniques. The low costs of volume semiconductor manufacturing make the micropyrovidicon-based array an attractive alternative for commercial and military detection systems. The planned detection system is based on a micropyrovidicon vacuum tube array fabricated using micro-machining techniques. Phase I demonstrated the feasibility of fabricating a single pixel micropyrovidicon device and the use of a miniature cold cathode electron source to detect an IR induced image on a pyroelectric element with a temperature resolution of 0.08°C/nA. Phase II will develop a base-line manufacturing process to integrate the pyroelectric detection array with the cold cathode array for signal detection and read-out. A prototype two dimensional 40 x 40 array micropyrovidicon detector will be delivered.

Anticipated Results / Potential Commercial Applications as described by the awardee: A successful Phase II project should produce an inexpensive, light drop-in replacement for an expensive heavy tube. In Phase III the scale-up and manufacture of a large format 512 by 512 micropyrovidicon detector array will be addressed. Lower parts and systems costs should allow proliferation of the technology into industrial, automotive, and domestic applications from intrusion detection to predictive maintenance and process control.

7

An Intelligent Intrusion Detection System Using a Fiber Optic Sensing Network--Optiphase, Inc., 7652 Haskell Avenue, Van Nuys, CA 91406-2005; (818) 782-0997
Mr. Ira Jeffrey Bush, Principal Investigator
Mr. Ira Jeffrey Bush, Business Official
DOE Grant No. DE-FG03-94ER81675
Amount: $597,532

Conventional intrusion detection systems which monitor large secure areas often generate false and "nuisance" alarms at rates well in excess of one per month (an objective for the security industry). The causes of these false and nuisance alarms include rapid air temperature and pressure variations, precipitation, seismic activity from nearby traffic, electromagnetic interference (EMI), and sensor self noise. Efforts to reduce error rates using smart processing of the sensor information have resulted in little or no improvement. This is because conventional intrusion detection approaches use non-linear sensing techniques which are oriented towards detecting events rather than accurately measuring them. The objective of Phase I was to investigate and demonstrate a fiber optic interferometric sensing approach which accurately measures intrusion-type events with high resolution, so that signal processing could effectively discriminate between true, false, and nuisance alarms. In Phase I, a 40 square foot distributed fiber sensor and analog electronic processor were developed and field tested with the following results: 100% intrusion alarming for an 80+ pound intruder; 0 false alarms and 0 nuisance alarms. In Phase II, a full scale intelligent intrusion detection system, providing coverage for a 100 meter long security zone, will be developed and field tested. Additionally, an intelligent digital processor will be developed to be used in conjunction with the fiber optic sensing approach. The objective is to identify events experienced by the zone deployed sensor so that "intruders" are detected with 100% probability, nuisance events are identified, and false alarm rates are less than one per month.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned fiber optic sensing approach should address an unlimited number of commercial security and safety applications, where low price, ease of deployment, high accuracy, and immunity to EMI are required. Commercial industrial coverage includes: intrusion detection, perimeter protection, and physical plant safety monitoring. This technology, given the proper price to volume ratios, could also extend to home security and safety applications.

8

Development of an Automated Radio Frequency Tagging Method for Tamper Protected Inventory Control of Special Nuclear Material Containers--RAND Technologies Corporation, 9461-B Silver King Court, Fairfax, VA 22031; (703) 352-0833
Mr. Alan C. Hurkamp, Principal Investigator
Mr. Donald K. Salmon, Business Official
DOE Grant No. DE-FG05-94ER81681
Amount: $598,691

DOE is responsible for the long term storage and protection of large quantities of special nuclear material (SNM). This material is stored within individual containers located in vaults at a number of widely scattered sites throughout the country. Special security and inventory measures are required to ensure that the SNM remains within the containers where it is stored and that it is not disturbed in any manner. Conventional security and inventory techniques are manpower intensive and often require exposure to radiation hazards. Studies show that automation of the SNM monitoring function would improve the level of security, reduce radiation exposure to DOE personnel connected with conducting physical inventories, and reduce real costs of maintaining inventory control of SNM. Based on literature research, site visits, and extensive discussions with key individuals at DOE and several National Laboratories, a detailed system specification was completed and published. This document formed the basis for the design of a prototype system. The design approach is based on a radio frequency tag polling concept that permits the rapid polling of small tags attached to individual SNM containers. The design incorporates a highly effective tamper indicating device (TID) which detects changes in the weight of the container. In addition there is a provision for the transmission of data from other sensors (e.g., radiation signature) that may be added to the system in the future. The battery powered tags will be highly reliable so that reentry into a vault for tag or battery replacement is minimal. Key elements of this system have been fabricated and tested in order to demonstrate the feasibility of this approach. The results of initial testing confirm that the specifications can be met in an affordable and practical package. The Phase II project will design and fabricate a full function prototype system to include the development of specialized integrated circuits. This prototype will be tested using a vault, currently unused, to best simulate realistic conditions.

Anticipated Results / Potential Commercial Applications as described by the awardee: This project will demonstrate a full capability prototype system for SNM inventory monitoring using the tag polling design. This system should meet all of DOE's performance requirements at an affordable price, and, when fielded, should repay its cost rapidly through reduced requirements for manual SNM inventory inspections. The hardware and software being developed for this project should have numerous commercial applications in such areas as high value item inventory management, material and personnel tracking, transportation (toll collection, remote truck weighing, etc.), and many others.

9

An Ultra-Compact Cesium Iodide/Mercuric Iodide Gamma-Ray Scintillation Spectrometer--Xsirius, Inc., 1220 Avenida Acaso, Camarillo, CA 93012; (805) 484-8300
Dr. Bradley E. Patt, Principal Investigator
Dr. Jan S. Iwanczyk, Business Official
DOE Grant No. DE-FG03-94ER81687
Amount: $599,846

Ultra-compact hand held units for assaying low-grade radioactive materials are needed for cleanup activities and facility transition. New technology is required to overcome limitations such as inferior energy resolution for photomultiplier tubes (PMTs) and silicon devices; disadvantages such as large size, voltage regulation, and magnetic field sensitivity of PMTs; and the bulky apparatus associated with cryogenic cooling for direct gamma detectors such as germanium. This project will couple large mercuric iodide (HgI_2) photodetectors to highly optimized cesium iodide (thallium) [CsI(Tl)] scintillators in order to increase the energy resolution and decrease the size and weight of detector systems. Phase I confirmed the feasibility of growing high quality HgI_2 crystalline material and fabricating large-area photodetectors with diameters up to one inch. Scintillator/photodetector pairs and new optimized electronics were constructed and evaluated. Phase II will build and test a prototype demonstration detector instrument exhibiting energy resolution of 5% or better for 662 keV gamma rays. The instrument will contain a primary detector composed of novel tapered CsI(Tl) scintillator optically coupled to one or more HgI_2 photodetectors. The dimensions of the primary detector will provide similar gamma-collection efficiency to a standard 2 inch by 3 inch NaI detector. The system will employ low noise electronics and will be packaged in a rugged fieldable format.

Anticipated Results / Potential Commercial Applications as described by the awardee: The instrument design features which will be developed should have application to many gamma ray spectroscopy and monitoring applications. The particular advantages (small size, high detection efficiency, superior ruggedness, and good energy resolution) of the HgI_2 based system for gamma detection can be used in instrumentation throughout the gamma ray spectroscopy community and should find widespread use in space instruments, high energy physics research, health physics, personnel monitoring, medical research, and other commercial applications.

APPENDIX A

Alphabetical List of Awardees

Advanced Technology Materials, Inc. *6*
Mr. Ward C. Stevens, Business Official
7 Commerce Drive
Danbury, CT 06810-4131
(203) 794-1100

AndCare, Inc. *1*
Mrs. Camille Blommer, Business Official
2810 Meridian Parkway, Suite 152
Durham, NC 27713
(919) 544-8220

Atlantic Aerospace Electronics Corporation . . *3*
Dr. Theodore Bially, Business Official
470 Totten Pond Road
Waltham, MA 02154
(617) 890-4200

Optiphase, Inc. *7*
Mr. Ira Jeffrey Bush, Business Official
7652 Haskell Avenue
Van Nuys, CA 91406-2005
(818) 782-0997

Physical Optics Corporation *2, 4*
Ms. Patty Shaw, Business Official
20600 Grammercy Place, Suite 103
Torrance, CA 90501
(310) 320-3088

RAND Technologies Corporation *8*
Mr. Donald K. Salmon, Business Official
9461-B Silver King Court
Fairfax, VA 22031
(703) 352-0833

Stange Associates *5*
Mr. L. G. Stange, Business Official
5853 Finecrest Drive
Rancho Palos Verdes, CA 90274
(310) 541-9574

Xsirius, Inc. *9*
Dr. Jan S. Iwanczyk, Business Official
1220 Avenida Acaso
Camarillo, CA 93012
(805) 484-8300

References denote entry numbers

APPENDIX B

State List of Awardees

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References denote entry numbers

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References denote entry numbers

SELECTION STATEMENT FOR PHASE I AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM FOR FISCAL YEAR 1995 (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0629)

U.S. DEPARTMENT OF ENERGY
GERMANTOWN, M.D. 20874
JULY 12 , 1995

SELECTION STATEMENT FOR PHASE I AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM FOR FISCAL YEAR 1995 UNDER PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0629

As a former chairman of the SBIR Application Score Verification Panel that had been appointed to evaluate Phase I grant applications for the SBIR program, I am familiar with the Panel's evaluation procedures and its methodology. I have received reports from the Technical Topic Managers (TTMs) who were responsible for the review of the 44 technical topic areas listed in the solicitation. I believe that the Panel has proceeded in accordance with applicable laws and regulations, that the evaluation was thorough and equitable, and that the information presented formed a sound basis for selection. Consequently, I have selected 201 applications received under this solicitation for negotiation for award of Phase I Fiscal Year (FY) 1995 SBIR grants. This statement describes the procurement and sets forth the basis for my selection decision.

Procurement Description

The Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564), requires that each Federal agency with an extramural research or research and development budget exceeding $100 million establish an SBIR program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies over the 18 years of the program are as follows:

Fiscal Year	SBIR Set Aside (%)
1983	0.2
1984	0.6
1985	1.0
1986-1992	1.25
1993-1994	1.5
1995-1996	2.0
1997-2000	2.5

Public Laws 97-219 and 102-564 also prescribe that the SBIR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the SBIR program. This phase will have a period of performance which is typically six months in duration. Awards during this phase will be up to $75,000. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $750,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-SBIR funded Federal contracts for products or services intended for use by the U.S. Government.

In response to the first twelve years of the program (FYs 1983-1994), DOE received a total of 16,728 Phase I proposals. Of these proposals, 1766 resulted in Phase I contracts or grants, and of these 726 were subsequently selected for Phase II awards. The results of the 1995 Phase I grant applications discussed here will be added to the above figures which demonstrate the high level of volume and interest in the SBIR program.

Applications Received

Outreach efforts for the DOE SBIR program were considerable. DOE mailed out approximately 15,000 1995 solicitations to past recipients on an extensive mailing list and to other individuals requesting copies. In addition, the SBIR solicitation was advertised in the Commerce Business Daily on November 14, 1994. It also received coverage in trade journals and newsletters and in various Small Business Administration information releases and conferences.

A total of 1569 applications were received in response to the solicitation. The solicitation listed 44 technical topic areas to which applicants could respond. The list of technical topic areas and the number of applications received in each area are as follows:

1.	Novel Materials for Sustainable Energy Development	93
2.	Advanced Instrumentation to Exploit Neutron and Photon Sources	24
3.	Ceramic Fibers and Fiber Coatings for High Temperature Applications	27
4.	Chemical Sciences Research	98
5.	Information Infrastructure for the National Information Initiative	17
6.	High Temperature Superconductivity for Energy Applications	70
7.	Improved Materials for the Pulp and Paper Industry	17
8.	Advanced Drilling Technology	17
9.	Advanced Environmental Monitoring Technology	92
10.	Human Genome	16
11.	Computerized Processing of Biological Data	10
12.	Atmospheric Measurement and Sampling Technologies	57
13.	Medical Applications	16
14.	High Energy Physics Educational and Teaching Aids	32
15.	Technology and Instrumentation for High Energy Accelerators	59
16.	High Energy Physics Data Processing and Detector Instrumentation	21
17.	Nuclear Physics Instrumentation and Techniques	32
18.	Nuclear Physics Accelerator Technology	10
19.	Plasma Confinement Systems Technology	45
20.	Fusion Energy Systems	14
21.	Plasma Diagnostics	29
22.	Technology and Instrumentation for Heavy Ion Fusion Accelerators	6
23.	Cost-Effective Methods for Coating Polymers	24
24.	Research on the Electronic Exchange of Scientific and Technical Information Among Organizations	10
25.	Elemental Tritium Collection Technology	4
26.	Technology for Space Nuclear Propulsion and Power	40

27.	Measurement and Characterization of Materials in Civilian Nuclear Reactors	16
28.	Characterization, Monitoring, and Sensor Technologies for Radioactive and Hazardous Waste	21
29.	In-Situ Treatment of Metal Contaminated Soils and Groundwater	46
30.	Chemical Separation Processes for Waste Treatment	40
31.	Computer Storage and Analysis for Nonproliferation Data Collection	14
32.	Laser Technology for Chemical Analysis for Nonproliferation Activities	34
33.	Improved Sensor Technology for National Security and Nonproliferation of Weapons	27
34.	Environmental Technology for Natural Gas, Oil, and Coal	86
35.	Advanced Recovery of Oil	30
36.	Natural Gas Supply	55
37.	Natural Gas Utilization	47
38.	Advanced Coal-Based Power Systems	77
39.	Advanced Fossil Fuels Research	51
40.	Improved Technology for Obtaining Recyclable Material from Municipal Solid Waste	35
41.	Lightweight Composite Material for Automotive Structures	17
42.	Hybrid Electric Vehicle Technology	19
43.	Modular and Panelized Passive Solar Buildings	31
44.	Technical Improvements for Advancing Photovoltaic Applications	42

One application received could not be assigned to a specific topic or subtopic.

Of the 1569 applications received, 61 were eliminated for administrative reasons; DOE staff determined that these applications failed to meet one or more material requirements of the solicitation. Ten applications were withdrawn by the proposing firms.

The remaining 1498 were judged on a competitive basis in a two-step process. The first step of that process was a screening by the TTMs and the DOE staff knowledgeable in the topic area to determine the relevance of each application to a chosen topic by the extent to which it responded to a specific topic area. Then it was determined whether each application was for research or research and development, whether it provided sufficient information for a full evaluation, whether it was duplicative of other ongoing or previous efforts, and finally, whether it was of sufficiently high quality for award. Six hundred thirty-two applications were eliminated after the first step technical review. The 866 applications found to be relevant were evaluated in the second step according to criteria listed in the solicitation and set out below.

Selection Criteria and Rationale

For each of the 44 technical topic areas listed in the solicitation, there was a TTM who, along with reviewers both internal and external to DOE - selected from among DOE Laboratory personnel, university researchers, and private industry personnel - evaluated and scored applications against the following criteria with equal consideration given to each.

(1) The scientific/technical quality of the research in the Phase I grant application.

(2) The degree of innovation demonstrated by the grant application.

(3) The qualifications of the Principal Investigator, other key staff, and consultants, if any, and the level of adequacy of available or obtainable instrumentation and facilities.

(4) The anticipated benefits, technical and/or economic, of the proposed research (Phase I and Phase II), if successful, with special emphasis on the likelihood that the project will attract further funding for product or process development after the SBIR support expires.

(5) The soundness and level of adequacy of the Phase I proposed work plan to show progress toward proving the feasibility of the concept.

An additional score, based on the value of the proposed work to the DOE program area responsible for the topic, was assigned by the TTM and added to the score based on the five criteria addressed by the reviewers, to make a total score for each application. This sixth score was given the same weight as the scores for each of the other five criteria.

A representative from each DOE technical program area reviewed the scoring for all grant applications within the program area and ranked them by total score. Each representative then designated a set number of grant applications with the highest total scores as highest priority, and a second set number with the next highest total scores as second highest priority. (The number in each set was determined by the SBIR Program Manager, based on each program area's budgetary contribution to SBIR.)

An Application Status Verification Panel (ASVP), consisting of technical staff from both within and without DOE, was established to ensure relative uniformity, across all DOE technical program areas, of the scoring and to ensure that scores were based on meaningful technical reviews. The ASVP was also chartered to ensure that there was consistency of scoring within topics. However, the sixth criterion on value to the program was not subject to ASVP review.

I have examined the evaluation documentation presented by the TTMs and the DOE technical program area representatives. I have also carefully reviewed the recommendations of the ASVP and have agreed that the evaluations of the TTMs and the technical program representatives and the recommendations of the ASVP provided valid bases upon which to make a selection. Therefore, based on those recommendations, and in consideration of applications whose funding would contribute to a programmatically-balanced set of SBIR-supported projects, I have selected 201 applications for negotiations. These include

130 applications designated as highest priority by the technical program representatives. The other 71 applications selected for award were from applications not designated as highest priority, and included all of those that received the highest technical rating. The remaining applications were selected from applications designated as second highest priority and included all applications within this group that were within one point of the highest possible technical rating. The rest were selected from among applications within this group that were rated two points below the highest technical rating, on the basis of (1) program balance and (2) the amount of Phase III funding received for previous DOE SBIR Phase II projects. It is my view that these applications represent outstanding technical quality and are worthy of selection for this program.

Selected Applications

Appendix A is a listing of the applications selected for negotiations leading to award. The SBIR program is an ongoing one, and continued participation in later solicitations is strongly encouraged.

Samuel J. Barish

Samuel J. Barish
SBIR Program Manager

Date: 7/13/95

Attachment:
List of Grant Applications
Recommended for Awards

Appendix A

DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1995 AWARDS

TOPIC: NOVEL MATERIALS FOR SUSTAINABLE ENERGY DEVELOPMENT

Aspen Systems, Inc. 184 Cedar Hill Street Marlborough, MA 01752-3017	Low Cost, Contamination-Tolerant Electrocatalysts for Low-Temperature Fuel Cells
Cordec Corporation P.O. Box 188 Lorton, VA 22199-0188	Laser Consolidation of Silicon Carbide/Titanium Metal Composite Turbine Rings
Giner, Inc. 14 Spring Street Waltham, MA 02154-4497	An Integrated Catalyst/Collector Structure for Regenerative Proton-Exchange Membrane Fuel Cells
Harvest Technology 14431 Ventura Boulevard, #273 Sherman Oaks, CA 91423-2606	Molten Film High-Intensity Paper Drying
ISM Technologies, Inc. 9965 Carroll Canyon Road San Diego, CA 92131-1105	Conformal Source Ion Implantation
Lynntech, Inc. 7610 Eastmark Drive Suite 105 College Station, TX 77840-4024	Synthesis and Application of a Novel Electrode Material for Use in Proton-Exchange-Membrane Fuel Cells Capable of Using Simple Organic Fuels and Fuel Reformate
Media and Process Technology, Inc. 1155 William Pitt Way Pittsburgh, PA 15238-1368	A Steam-Resistant Hydrogen Selective Ceramic Membrane for Fuel Cell Applications
Millennium Materials, Inc. 120 Sherlake Drive Knoxville, TN 37922-2307	Silicon Hexaboride Reinforced Aluminum Ingot Material Development for the Transportation Industry
Nanomaterials Research Corporation 10960 North Stallard Place Tucson, AZ 85737-9527	Nanostructured Insterstitial Alloys as Catalysts for Direct Energy Applications

Precision Combustion, Inc. 25 Science Park New Haven, CT 06511-1968	An Integrated Catalyst/Substrate for Catalytic Combustion
Selee Corporation 700 Shepherd Street Hendersonville, NC 28792-6472	A Highly Efficient and Low Emission Catalytic Radiant Burner
Structured Materials Industries, Inc. 120 Centennial Avenue Piscataway, NJ 08854-3908	Light Emitting Devices Based on Germanium Quantum Crystals in a Direct Bandgap Matrix (Aluminum Nitride)
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033-1916	Low Cost, Novel Precursors to Beta" Alumina Solid Electrolyte
Technology Assessment & Transfer, Inc. 133 Defense Highway Suite 212 Annapolis, MD 21401-7015	A Nanolayer Coating for Dry Machining

TOPIC: ADVANCED INSTRUMENTATION TO EXPLOIT NEUTRON AND PHOTON SOURCES

Applied Physics Technologies 25 East Loop Road Stony Brook, NY 11790-3350	A New Microstrip Gas Chamber for Synchrotron Experiments
Intraspec, Inc. P.O. Box 4579 Oak Ridge, TN 37831-4579	A Two Dimensional Semiconductor Imaging Array for Scattered Cold Neutrons
Mission Support, Inc. P.O. Box 511283 Salt Lake City, UT 84151-1283	A Thermal Neutron Detector Based upon a Lanthanum Boron Germanate Scintillator
SSG, Inc. 150 Bear Hill Road Waltham, MA 02154-6397	Advanced Silicon Carbide and Beryllium/Aluminum Alloy Integrally Cooled X-ray Synchrotron Mirrors

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TOPIC: CERAMIC FIBERS AND FIBER COATINGS FOR HIGH TEMPERATURE APPLICATIONS

Hyper-Therm High-Temperature Composites, Inc. 18411 Gothard Street Units B and C Huntington Beach, CA 92648-1235	Pseudo-Porous Zirconium Carbide Fiber Coating for Environmentally Durable Silicon Carbide/Silicon Carbide Composites
Ultramet 12173 Montague Street Pacoima, CA 91331-2210	Controlled Shear Strength Oxidation-Resistant Interfacial Coatings

TOPIC: CHEMICAL SCIENCES RESEARCH

Analysis Consultants 21831 Zuni Drive Lake Forest, CA 92630-3553	A New Type of Acoustical Sensor for Chemical Measurements
Compact Membrane Systems, Inc. 325 Hampton Road Wilmington, DE 19803-2425	Chemically Resistant Gas Separation Perfluoromembranes
Consultec Scientific, Inc. 725 Pellissippi Parkway Suite 110 Knoxville, TN 37932-3300	A Miniature Multi-Chemical Sensor Using Micro-Cantilevers
EIC Laboratories, Inc. 111 Downey Street Norwood, MA 02062-2668	High Capacity Carbon Anodes for Lithium Ion Batteries
Microsensor Systems, Inc. 62 Corporate Court Bowling Green, KY 42103-7023	Advanced Chemiresistor Devices as Micron Size Sensors for the Rapid, On-Line Measurement of Chemical Vapors

TOPIC: HIGH TEMPERATURE SUPERCONDUCTIVITY FOR ENERGY APPLICATIONS

American Superconductor Corporation 2 Technology Drive Westborough, MA 01581-1799	A Low Cost, High Temperature Superconductor Wire Manufacturing Technology
American Superconductor Corporation 2 Technology Drive Westborough, MA 01581-1799	Development of a Process Management Technology for the Manufacture of High Temperature Superconductors to Improve Conductor Quality

American Superconductor Corporation 2 Technology Drive Westborough, MA 01581-1799	Superconducting Wires for Alternating Current Magnet Applications
American Superconductor Corporation 2 Technology Drive Westborough, MA 01581-1799	High Current Density High Temperature Superconductor Composite Conductors
Illinois Superconductor Corporation 451 Kingston Court Mount Prospect, IL 60056-6068	A Resistive Fault Current Limiter Based on Highly Directional Superconductor Thick Film Conductors
Intermagnetics General Corporation 450 Old Niskayuna Road Latham, NY 12110-0461	A Low Cost, Windable Yttrium-Barium-Copper-Oxide Conductor by Continuous Ion Beam Assisted Deposition/Metal Organic Chemical Vapor Deposition on a Metallic Substrate Tape
Quality Engineering Associates, Inc. 25 Adams Street Burlington, MA 01803-4915	An In-Process Quality Monitoring System for High Temperature Superconducting Wire Manufacturing

TOPIC: IMPROVED MATERIALS FOR THE PULP AND PAPER INDUSTRY

Climax Research Services 39205 Country Club Drive Suite C-40 Farmington Hills, MI 48331-3495	A New Alloy for Refiner Plates in the Pulp and Paper Industry
E. R. Johnson Associates, Inc. 9302 Lee Highway Suite 700 Fairfax, VA 22031-1214	Development of Novel Iron-Chromium-Silicon Alloys for Use in Kraft Recovery Boilers
Eltron Research, Inc. 2830 Wilderness Place, #E Boulder, CO 80301-5455	Refractory Coatings for Improved Papermaking
Stirling Technologies Inc. 102 Walton Lane Oak Ridge, TN 37830-8237	An Energy Efficient Design for a Surface Treatment Process which Improves Wear Properties of Materials

TOPIC: ADVANCED DRILLING TECHNOLOGY

Advanced Technology Materials, Inc. 7 Commerce Drive Danbury, CT 06810-4169	High Temperature Acoustic Sensors for Drill Monitoring
Maurer Engineering Inc. 2916 West T. C. Jester Houston, TX 77018-7098	A Fully Instrumented Oil-Field Drill Bit for Use with Smart Drilling Systems

TOPIC: ADVANCED ENVIRONMENTAL MONITORING TECHNOLOGY

Adelphi Technology, Inc. 2181 Park Boulevard Palo Alto, CA 94306-1543	An Inexpensive, Electronically Tunable Chemical Sensor
Clinical Micro Sensors, Inc. 428 South Sierra Bonita Avenue Pasadena, CA 91106-3502	Direct Detection of Biological Microorganisms Based on Electron Transfer through DNA
Durability, Inc. 1872 Pratt Drive Blacksburg, VA 24060-6363	A Portable Supercritical Fluid Extraction System for Direct Extraction of Heavy Metals from Wastewater
Giner, Inc. 14 Spring Street Waltham, MA 02154-4497	A Multiple Sensor for Ecosystem Monitoring
Microbial Insights, Inc. 201 Center Park Drive Suite 1440 Knoxville, TN 37922-2105	Integrated Analysis of Lipid Biomarkers, DNA, and Pollutants in Sediment Using Supercritical Fluids
Thermalytics, Inc. 2545 Boatman Avenue West Sacramento, CA 95691-3817	A Real-Time, In-Situ Monitor of Remediation by Biological and Chemical Processes

TOPIC: HUMAN GENOME

Applied Genetics Laboratories, Inc. 1335 Gateway Drive Suite 2001 Melbourne, FL 32901-2637	Microgenetics: Techniques for Screening Large Insert Libraries

BIODE, Inc. 2 Oakwood Road Cape Elizabeth, ME 04107-2025	A Piezoelectric Biosensor Using Peptide Nucleic Acids for Triplex Capture

TOPIC: COMPUTERIZED PROCESSING OF BIOLOGICAL DATA

A. J. Boggs & Company 4136 Shoals Drive Okemos, MI 48864-3468	A Graphical Ad Hoc Query Interface Capable of Accessing Heterogeneous Public Genome Databases
ApoCom, Inc. 601 South Concord Street Suite LLD Knoxville, TN 37919-3340	GRAIL-GenQuest: A Comprehensive Computational System for DNA Sequence Analysis
X-ray Instrumentation Associates 2513 Charleston Road Suite 207 Mountain View, CA 94043-1607	Large Detector Array X-ray Absorption Spectroscopy Data Acquisition and Analysis Software

TOPIC: ATMOSPHERIC MEASUREMENT AND SAMPLING TECHNOLOGIES

Aerodyne Research, Inc. 45 Manning Road Billerica, MA 01821-3976	An Optical Water Vapor Sensor for Unmanned Aerial Vehicles
Yankee Environmental Systems, Inc. 101 Industrial Road P.O. Box 746 Turners Falls, MA 01376-0746	An Automated Infrared Shadowdisk Radiometer
Yankee Environmental Systems, Inc. 101 Industrial Road P.O. Box 746 Turners Falls, MA 01376-0746	Development of a Low Cost, Narrowband, Solar Ultraviolet Spectroradiometer for Field Use

TOPIC: MEDICAL APPLICATIONS

Mission Support, Inc. P.O. Box 511283 Salt Lake City, UT 84151-1283	An Advanced Scintillator for Medical Imaging

TOPIC: HIGH ENERGY PHYSICS EDUCATIONAL AND TEACHING AIDS

Context Productions 1495 Masonic Avenue San Francisco, CA 94117-4525	Interactive Multimedia Software for Fundamental Particles and Forces
Harrison Scientific Corporation Mt. Agassiz P.O. Box 660 Bethlehem, NH 03574-0660	An Apparatus for Demonstrations and Hands-On Experiments in the Science and Technology of Charged Particles in Vacuum
Invocon, Inc. 9001 Interstate 45 South Suite 530 Conroe, TX 77385-8703	An Interactive System for Educational Instruction in High Energy Physics
Quantum Research Services, Inc. 5410 Apex Highway Suite W Durham, NC 27713-9434	Interactive Particle Detector Teaching Aids Based on Plastic Scintillators

TOPIC: TECHNOLOGY AND INSTRUMENTATION FOR HIGH ENERGY ACCELERATORS

Duly Research, Inc. 1912 MacArthur Street Rancho Palos Verdes, CA 90732	Breaking the Oscillation Barrier in High Power Microwave Tubes
FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236	An Induction Modulator for a Relativistic-Klystron Two-Beam Accelerator
FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236	Suppression of Voltage Breakdown in High-Gradient Radiofrequency Cavities
Field Effects, Inc. 6 Eastern Road Acton, MA 01720-5801	A Thermally Stable Iron Core Permanent Magnet Dipole Utilizing a Flux Shunt
Fusion and Accelerator Research 3146 Bunche Avenue San Diego, CA 92122-2247	Design of a Radiofrequency-Extraction Structure for a Relativistic Klystron Two-Beam-Accelerator

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G. H. Gillespie Associates, Inc. P.O. Box 2961 Del Mar, CA 92014-5961	An Intelligent Graphics Interface for Particle Optics and Accelerator Design
Haimson Research Corporation 3350 Scott Boulevard Building 60 Santa Clara, CA 95054-3122	A Relativistic Klystron High Power Ceramic Window and Output Structure to Maximize Conversion Efficiency
Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523-1101	Development of Low-Cost Cryogenic Amplifiers for High-Resolution Particle Detectors in High Energy Physics Research
IGC Advanced Superconductors, Inc. 1875 Thomaston Avenue Waterbury, CT 06704-1039	Enhanced Flux Pinning at High Fields in Niobium-Titanium-Tantalum by Magnetic Artificial Pinning Centers
Integrated Applied Physics, Inc. 2701 Plaza Del Amo Suite 702 Torrance, CA 90503-7314	An Efficient, Cost-Effective Power Modulator for Advanced Klystrons
MDS Company 1955 Mountain Boulevard Suite 101 Oakland, CA 94611-2812	Development of a 10 Megawatt L-Band Klystron Amplifier
North Star Research Corporation 9931 Lomas Northeast Suite A Albuquerque, NM 87112-5278	Efficient Thyratron/Transformer Modulators for Radiofrequency Acclerators
Omega-P, Inc. 202008 Yale Station New Haven, CT 06520	A Vacuum Beat Wave Accelerator
Omega-P, Inc. 202008 Yale Station New Haven, CT 06520	A Microwave Inverse Cerenkov Accelerator
Omega-P, Inc. 202008 Yale Station New Haven, CT 06520	A High Power Harmonic Magnicon

Schonberg Research Corporation 3300 Keller Street Building 101 Santa Clara, CA 95054-2612	A Microwave Structure for Charged Particle Multiple Beam Devices
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545-3386	Development of Artificial Pinning Center Niobium-Titanium Superconductors with Very High Residual Resistivity Ratio Aluminum Stabilizers

TOPIC: HIGH ENERGY PHYSICS DATA PROCESSING AND DETECTOR INSTRUMENTATION

3D-Computing 900 Hideaway Place DeSoto, TX 75115-5213	A Three Dimensional Flow Parallel-Processing System for Fast Programmable Real-Time Applications
Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523-1101	An Interleaved 10-bit Superconducting Flash Analog-to-Digital Converter with 2.5 Gigahertz Input Bandwidth
Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523-1101	Real-Time Digital Error Correction for Improved Analog-to-Digital Conversion
Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523-1101	An All-Digital, Multi-Hit Time-to-Digital Convertor Based on Superconductive Digital Counters
LeCroy Research Systems Corporation 700 South Main Street Spring Valley, NY 10977-6437	A High Resolution Multi-hit Time to Digital Converter Integrated Circuit

TOPIC: NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

Intraspec, Inc. P.O. Box 4579 Oak Ridge, TN 37831-4579	A Segmented Deep Depletion Depth Silicon Detector and Application Specific Integrated Circuits Signal Conditioning Systems for Physics Research
MetaStable Instruments, Inc. 1807 Vichy Road Rolla, MO 65401-2248	A Polarized (Spin Aligned) High Density Helium Gas Target

NanoSystems Inc. 29 Cambridge Circle New Milford, CT 06776-3921	Microporous Alumina Microchannel Plates
Radiation Monitoring Devices, Inc. 44 Hunt Street Watertown, MA 02172-4624	Novel Avalanche Photodiode Arrays for Ultraviolet Light Detection
Rais Enterprises, Inc. 6393 Nancy Ridge Drive, #B San Diego, CA 92121-2247	Cesium Iodide Bromide and Cesium Iodide Chloride Scintillators for High-Rate Applications
Spire Corporation One Patriots Park Bedford, MA 01730-2396	Low-Cost, Large-Area, High-Resistivity Substrates for Gas Microstrip Detectors

TOPIC: NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

Astralux, Inc. 2386 Vassar Drive Boulder, CO 80303-5763	A High Power High Frequency Transistor
Atlas Technologies, Inc. 2760 Washington Street Port Townsend, WA 98368-4615	Manufacturing Technologies, Improved Performance, and Cost Reduction of Superconducting Radiofrequency Resonant Niobium Cavities
Hypres, Inc. 175 Clearbrook Road Elmsford, NY 10523-1101	Forty Gigahertz Acquisition of Bunch Profile, Position, and Arrival Time for Particle Accelerator Diagnostics and Control
NZ Applied Technologies, Inc. 150-C New Boston Street Woburn, MA 01801-6204	A High Brightness Cold Cathode Electron Beam Source

TOPIC: PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

Calabazas Creek Research 20937 Comer Drive Saratoga, CA 95070-3753	Development of a One Megawatt Continuous Wave Waterload for Gyrotons with a Gaussian Output Beam

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Calabazas Creek Research 20937 Comer Drive Saratoga, CA 95070-3753	Development of a Multi-Stage Depressed Collector for a One Megawatt Continuous Wave Gyrotron
Energy Science Laboratories, Inc. 6888 Nancy Ridge Drive San Diego, CA 92121-2232	A High Conductance Thermal Interface
Fiber Materials, Inc. 5 Morin Street Biddeford, ME 04005-4497	Low Cost, High Conductivity Plasma Facing Components
IGC Advanced Superconductors, Inc. 1875 Thomaston Avenue Waterbury, CT 06704-1039	Structure-Property Relationships of Internal-Tin Niobium Tin
Omega-P, Inc. 202008 Yale Station New Haven, CT 06520	A High Power Electron Gun
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545-3386	Fabrication of a Flexible Reacted Niobium Tin Cable for Applications in React and Wind Magnets
Surmet Corporation 33 B Street Burlington, MA 01803-3406	Fabrication of Copper-Backed Dense Tungsten Plasma Facing Component Armor
Surmet Corporation 33 B Street Burlington, MA 01803-3406	Low Temperature Fabrication of Copper Swirl Tubes for the International Thermonuclear Experimental Reactor
Technical Research Associates 2257 South 1100 East Salt Lake City, UT 84106-2379	A Discontinuous Fiber Composite Interlayer for Increased Brazed Joint Reliability
Thermacore, Inc. 780 Eden Road Lancaster, PA 17601-4794	A Helium-Cooled Faraday Shield Using Porous Metal Cooling

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TOPIC: FUSION ENERGY SYSTEMS

Energy Applications and Systems, Inc. 3198 Camino Arroyo Carlsbad, CA 92009-7612	A Volumetric Neutron Source for Fusion Nuclear Technology Development
Karta Technology, Inc. 1892 Grandstand San Antonio, TX 78238-4507	Nondestructive Characterization of Radiation Embrittlement in Fusion Structural Materials Using Laser Ultrasound
Lanxide Corporation P.O. Box 6077 1300 Marrows Road Newark, DE 19714-6077	Low Cost Fabrication of Large Silicon Carbide/Silicon Carbide Composite Structures
Starfire Systems, Inc. 877 25th Street Watervliet, NY 12189-1903	Bonding of Ceramic Composites for Structural Applications in Fusion Energy Systems
TSI Research, Inc. 225 Stevens Avenue Solana Beach, CA 92075-2059	Study of a Spherical Tokamak Based Volumetric Neutron Source

TOPIC: PLASMA DIAGNOSTICS

Boston Physics 28 Commonwealth Avenue Boston, MA 02116-3111	Hardened Tomographic X-Ray Imaging Technology Development for Burning-Plasma Tokamak Fusion Reactors
Boulder Metric 2440 Kohler Drive Boulder, CO 80303-5251	Accurate Broadband Detectors for Plasma Diagnostics
Innovative Research and Technology 843 Yale Street Santa Monica, CA 90403-2229	A Reliable Density Profile Diagnostic for Next-Step Fusion Devices
InterScience, Inc. 105 Jordan Road Troy, NY 12180-8343	A Real-Time Multiple Source Video Compression and Storage System

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Millitech Corporation South Deerfield Research Park P.O. Box 109 South Deerfield, MA 01373-0109	**A 140 Gigahertz Plasma Diagnostic Imaging System**
Orincon Corporation 9363 Towne Center Drive **San Diego, CA 92121-3017**	**Real-Time Neural Network Analysis of Tokamak Current Profiles**

TOPIC: TECHNOLOGY AND INSTRUMENTATION FOR HEAVY ION FUSION ACCELERATORS

Advanced Ceramics Research, Inc. 841 East 47th Street Tucson, AZ 85713-5009	Solid Free-Body Formed Alumina-Tungsten Electrode Insulators for Heavy Ion Fusion Accelerators
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143-4228	Development of All-Solid-State Drivers for Heavy Ion Fusion Accelerators

TOPIC: RESEARCH ON THE ELECTRONIC EXCHANGE OF SCIENTIFIC AND TECHNICAL INFORMATION AMONG ORGANIZATIONS

American Research Corporation of Virginia P.O. Box 3406 Radford, VA 24143-3406	A Fuzzy Expert Systems-Based Standard Generalized Markup Language Interface for Access and Collaborative Authoring of Multi-Domain Technical Documents on a Wide Area Network
Soph-Ware Associates North 10 Post Street Suite 448 Spokane, WA 99201-0705	A Distributed Multimedia Architecture

TOPIC: ELEMENTAL TRITIUM COLLECTION TECHNOLOGY

Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706-9237	A Novel Tritium Collection Technology Using Fullerence Tritides

TOPIC: TECHNOLOGY FOR SPACE NUCLEAR PROPULSION AND POWER

Creare, Inc. P.O. Box 71 Etna Road Hanover, NH 03755-0071	A High Efficiency Dynamic Isotope Power Conversion System
Edtek, Inc. 7082 South 220th Street Kent, WA 98032-1910	Bandgap-Engineered Thermophotovoltaic Devices for High Efficiency Radioisotope Power
Hi-Z Technology, Inc. 6373 Nancy Ridge Drive San Diego, CA 92121-2247	Segmented Thermoelectric Elements for Isotope Power Systems
Hi-Z Technology, Inc. 6373 Nancy Ridge Drive San Diego, CA 92121-2247	Silicides for Space Power and Waste Heat Applications
Stirling Technology Company 2952 George Washington Way Richland, WA 99352-1653	A Modular Isotope Power System with General Purpose Heat Source Thermal Input and a Long-Life Stirling Converter

TOPIC: MEASUREMENT AND CHARACTERIZATION OF MATERIALS IN CIVILIAN NUCLEAR REACTORS

Physical Research, Inc. 25500 Hawthorne Boulevard Suite 2300 Torrance, CA 90505-6828	Rotating, In-Plane Magnetization and Magneto-Optic Imaging of Cracks under Coatings on Ferromagnetic Metals
Quest Integrated, Inc. 21414 68th Avenue South Kent, WA 98032-2439	A Modular Inspection System for Complete In-Service Examination of a Nuclear Reactor Pressure Vessel, Including the Beltline Region

TOPIC: CHARACTERIZATION, MONITORING, AND SENSOR TECHNOLOGIES FOR RADIOACTIVE AND HAZARDOUS WASTE

NITON Corporation 74 Loomis Street Bedford, MA 01730-0368	A New Method for X-Ray Fluorescence Analysis of Contaminated Materials

TOPIC: IN-SITU TREATMENT OF METAL CONTAMINATED SOILS AND GROUNDWATER

ISOTRON Corporation 13152 Chef Menteur Highway New Orleans, LA 70129-1807	Electrokinetically Enhanced Extraction of Radionuclides, Heavy Metals, and Organics from Soil Using Surfactant Micelles
Phytotech, Inc. 1 Deer Park Drive Suite I Monmouth Junction, NJ 08852-1920	Phytoextraction of Heavy Metal Contaminated Vadose Zone Soils

TOPIC: CHEMICAL SEPARATION PROCESSES FOR WASTE TREATMENT

Advanced Processing Technologies, Inc. P.O. Box 58131 Salt Lake City, UT 84158-0131	Differential Processing to Separate Radionuclide and Volatile Organic Compounds from Soil and Ground Water by Air-Sparged Hydrocyclone Technology
Drinkard Metalox, Inc. 2226 North Davidson Street Charlotte, NC 28205-1830	A Process to Denitrify Radioactive Waste Streams
Lynntech, Inc. 7610 Eastmark Drive Suite 105 College Station, TX 77840-4024	A Novel Approach to the Removal of High Concentrations of Nitrate and Nitrite from Aqueous Waste Streams
Materials and Systems Research, Inc. 62 East Cleveland Avenue Salt Lake City, UT 84115-5328	Ion-Selective Ceramic Membranes for Separation of Radioactive Wastes
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025-1516	Removal and Concentration of Heavy Metals and Radionuclides from Polluted Groundwater
Micro Composite Materials Corporation 4608-D Industry Lane Durham, NC 27713-5414	An Advanced Nuclear Air Precleaner
Solox 10635 King William Drive Dallas, TX 75220-2412	Destruction of Organic Pollutants in Radioactive Aqueous Waste Streams

TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033-1916	The Selective Removal and Recovery of Heavy Metals from Contaminated Waters

TOPIC: COMPUTER STORAGE AND ANALYSIS FOR NONPROLIFERATION DATA COLLECTION

AbTech Corporation 1575 State Farm Boulevard Suite 1 Charlottesville, VA 22901-8611	Data Fusion for Timely Screening of Treaty Verification Data

TOPIC: LASER TECHNOLOGY FOR CHEMICAL ANALYSIS FOR NONPROLIFERATION ACTIVITIES

Aculight Corporation 40 Lake Bellevue Suite 100 Bellevue, WA 98005-2480	A Tunable Solid State Source Driven by a High Performance Diode Pumped Ytterbium Laser
AstroPower, Inc. Solar Park Newark, DE 19716-2000	Gallium Phosphide Ultraviolet Diode Arrays
Crystal Associates, Inc. 15 Industrial Park Waldwick, NJ 07463-1512	Development of Modulator Quality Rubidium Titanyl Arsenate Crystals for Remote Sensing Laser Systems
Deacon Research 2440 Embarcadero Way Palo Alto, CA 94303-3313	Rugged, Tunable Infrared Laser Sources
INRAD, Inc. 181 Legrand Avenue Northvale, NJ 07647-2498	Development of Gallium Selenide Nonlinear Crystals
INRAD, Inc. 181 Legrand Avenue Northvale, NJ 07647-2498	A Mid-Infrared Laser for Remote Sensing of Chemicals
Lightning Optical Corporation 431 East Spruce Street Tarpon Springs, FL 34689-4015	Development of Laser Materials and Rugged Coatings as Components for Tunable Ultraviolet Laser Systems

TOPIC: IMPROVED SENSOR TECHNOLOGY FOR NATIONAL SECURITY AND NONPROLIFERATION OF WEAPONS

Dynamics Technology, Inc. 21311 Hawthorne Boulevard Suite 300 Torrance, CA 90503-5610	Resonant Electromagnetic Detection and Mapping of Deeply Buried Cable Networks
GWR Instruments, Inc. 10623 Roselle Street San Diego, CA 92121-1506	A Superconducting Gravity Gradiometer for Detection of Underground Targets
Microsensor Systems, Inc. 62 Corporate Court Bowling Green, KY 42103-7023	Chemical Microsensor Arrays as Integrated Chip Compatible Devices for Chemical Weapons Nonproliferation Inspection
Reinholdtsen Measurement Systems 3767 Bay Road Menlo Park, CA 94025-1917	Hand Recognition for Access Control

TOPIC: ENVIRONMENTAL TECHNOLOGY FOR NATURAL GAS, OIL AND COAL

ADA Technologies, Inc. 304 Inverness Way South Suite 110 Englewood, CO 80112-5828	Improved Sensitivity for Environmental Monitors through Innovative Application of Wavelets
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DOE/ER-0654

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE I AWARDS

1995

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager
19901 Germantown Road
Germantown, MD 20874-1290

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PREFACE

The SBIR program enables DOE to obtain effective, innovative solutions to important problems through the private sector, which has a commercial incentive to pursue the resulting technology and bring it to the marketplace. The growing number of awardees, many of them started in business in response to SBIR solicitations, is becoming a significant resource for the solution of high risk, high technology problems for the Department. As detailed below, this publication describes the technical efforts for SBIR Phase I awards in 1995. It is intended for the educated layman, and may be of particular interest to potential investors who wish to get in on the ground floor of exciting opportunities.

The Federal SBIR Program

This program, now completing its thirteenth year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Eleven Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over $100 million. The agencies were required to set aside 2% of those budgets in Fiscal Year (FY) 1995 to fund SBIR projects. (This amounted to about $69 million in FY 1995 for the Department of Energy.) Each agency solicits proposals from small science- and technology-based US firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to $75,000. Phase II is the principal research or R&D effort, and the awards were as high as $750,000 in FY 1995 for work to be performed in a period of up to two years. Phase III is the commercial application of the research or R&D effort by the small businesses using non-Federal funding or, alternatively, it may involve follow-on non-SBIR Federal contracts for products or services desired by the Government. The program continues to strengthen the role that small, innovative firms play in meeting the Nation's research and development needs and in commercialization of ideas developed through federally funded R&D.

Phase I Awards for FY 1995

Contained in this booklet are abstracts of the Phase I awards made in FY 1995 under the DOE SBIR program. The 199 Phase I projects described here were selected in a highly competitive process from a total of 1,569 grant applications received in response to the 1995 DOE annual SBIR Solicitation. The selections for awards were made on scientific and technical merit, as judged against the specific criteria listed in the Solicitation. Conclusions were reached on the basis of detailed reports returned by reviewers drawn from DOE laboratories, universities, private industry, and government. (Any discrepancies noted in prior DOE releases naming the firms selected for awards are due either to the firm changing its name after the award selection or to the firm not proceeding to a signed grant.) It is expected that between one-third and one-half of the Phase I projects will be continued into Phase II.

The work described in the abstracts is novel, high-risk research, but the benefits will also be potentially high if the objectives are met. Brief comments on the potential applications, as described by the awardee, are given after each abstract. Individuals and organizations, including venture capital and larger industrial firms, with an interest in the research described in any of the abstracts are encouraged to contact the appropriate small business directly.

The DOE SBIR Program

DOE's FY 1995 annual Solicitation contained 44 technical topics in the areas of basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, energy efficiency and renewable energy, fossil energy, nuclear energy, environmental management, nonproliferation and national security, and environment, safety, and health. There was keen competition because awards are made solely on the basis of scientific and technical merit, regardless of the technical topic.

As a measure of the program's success, twelve DOE SBIR projects have received R&D-100 Awards from Research and Development Magazine, which selects the 100 most significant technical products each year. In addition, five DOE awardees were chosen among the 500 fastest-growing American private companies, in the December 1991 issue of Inc. Magazine, based on their growth in sales. Also, from the first seven cycles of awards (Phase II projects completed between 1986 and 1992), DOE SBIR winners have already received approximately $380 million in Phase III funding, which is double the SBIR support they were given. This number is expected to grow significantly in the next few years.

The DOE SBIR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. In the first year of Phase II awards (1984), a system was devised and implemented that allowed Phase I awardees who felt they were ready to submit their Phase II applications before their Phase I grants ended, to do so. For each of the twelve years in which Phase II awards have been made, such grantees who were chosen for Phase II funding were able to begin their projects without an interruption in funding. Since 1984, about 40 per cent of the Phase II awardees have had continuous funding between Phases I and II.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, DOE has instituted a special training project, supported by non-SBIR funds. For the past six years, successful Phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participation in the 1991 and 1993 projects, the SBIR companies have already received more than $50 million for commercialization of their SBIR research. More than half of the firms that completed these projects have received further funding for their work. Sources of capital that wish to consider participation in future programs should contact Dr. Robert Berger, U.S. Department of Energy SBIR Program, ER-33, 19901 Germantown Road, Germantown M.D. 20874-1290, (telephone 301-903-3054).

Samuel J. Barish
SBIR Program Manager
US Department of Energy
Germantown, MD 20874-1290

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NOVEL MATERIALS FOR SUSTAINABLE ENERGY DEVELOPMENT

1

Low Cost, Contamination-Tolerant Electrocatalysts for Low-Temperature Fuel Cells--Aspen Systems, Inc., 184 Cedar Hill Street, Marlborough, MA 01752-3017; (508) 481-5058
Dr. Jaeseok Ryu, Principal Investigator
Dr. Kang P. Lee, Business Official
DOE Grant No. DE-FG02-95ER81927
Amount: $74,998

Power generation from fuel cells via reformed gaseous fuel or direct methanol oxidation is a very attractive option for fuel cell vehicles or other mobile systems. One of the major roadblocks for large scale consumer applications of fuel cell technology is the high cost and limited supply of the noble metal-based catalysts, and catalyst poisoning. Metal carbides, such as molybdenum carbide and tungsten carbide (or their mixtures) exhibited high catalytic activity toward electro-oxidation of the methanol. In addition, these catalysts are tolerant of carbon monoxide contamination in the reaction zone. A major drawback associated with these materials is the difficulty in producing materials with high surface area. Usually, a very costly high temperature reduction and carburization, or a high energy process, such as ion implantation, is used to prepare high-surface-metal carbides. In Phase I, nanoscale group VI metal carbides will be produced utilizing nonconventional surfactants in a chemical reducing process. A technique of controlling composition, morphology, and particle size of these materials will be developed. The produced metal carbides will be evaluated with respect to surface area, particle size, particle morphology, size distribution, composition and crystallinity, presence of impurity phases, and localized electronic energy levels in the surface. Furthermore, the electrocatalytic activity of the nanoscale metal carbide produced will be investigated for the hydrogen and methanol oxidation.

Anticipated Results/Potential Commercial Applications as described by the awardee: If the planned research is successfully completed, the result will be non-noble metal-based catalysts that exhibit superior electrocatalytic activity. Furthermore, the performance of these catalysts will not be degraded by the contaminants, such as carbon monoxide and hydrogen sulfide, in the fuel gas stream. In addition, about 70% of the catalysts currently produced for industrial applications contain noble metals, such as platinum. Considering similar catalytic properties of platinum and tungsten carbides, inexpensive catalysts to be developed in this project may replace expensive noble metal-based catalysts that are currently used in industrial processes.

2

Laser Consolidation of Silicon Carbide/Titanium Metal Composite Turbine Rings--Cordec Corporation, P.O. Box 188, Lorton, VA 22199-0188; (703) 550-8044
Dr. Raymond J. Weimer, Principal Investigator
Mrs. Helen Pierides, Business Official
DOE Grant No. DE-FG02-95ER81945
Amount: $75,000

The extraordinary potential of high temperature composite materials to meet the engineering design challenges presented by advanced turbine engines is well known. Implementation has been seriously impeded by high cost and fabrication difficulties. Recently, continuous microcomposite monofilaments were produced by physical vapor deposition (PVD) methods to provide an improved alternative to drum-wound foil/fiber or plasma-sprayed monotapes. Such metal matrix composite (MMC) precursors are highly uniform and reproducible. Moreover, the local fiber volume fraction is precisely that desired in the consolidated macrocomposite structure, making the precursor ideal for a precision fiber placement and consolidation scheme. In the planned work, a unit consolidation process will be modeled and developed using laser energy to effect consolidation of continuous silicon carbide/titanium PVD MMC precursor wires. The feasibility of the approach will be demonstrated in Phase I by fabricating a subscale compressor ring for turbine engine applications. Phase II will explore the dimensions of the processing window, relying on parametric studies to model the consolidation response surface and produce a high-quality, full-scale demonstration ring.

Anticipated Results/Potential Commercial Applications as described by the awardee: Next generation commercial aircraft turbine engine components will benefit greatly from possible weight savings of more than 50%, compared to currently used superalloys. However, truly staggering economies will come from power plants using large land turbines, for which five percent more efficiency can result from a 100°F increase in operating temperature.

3

An Integrated Catalyst/Collector Structure for Regenerative Proton-Exchange Membrane Fuel Cells--Giner, Inc., 14 Spring Street, Waltham, MA 02154-4497; (617) 899-7270
Mr. Larry L. Swette, Principal Investigator
Dr. Anthony B. LaConti, Business Official
DOE Grant No. DE-FG02-95ER81977
Amount: $75,000

Dedicated proton-exchange membrane (PEM) fuel cells, electrolyzers and single-unit regenerative fuel cells (RFCs) have been identified as offering potential benefit to the electric vehicle and energy storage programs. Phase I will develop a novel gas-diffusion electrode/current-collection interface (GCI) structure which will yield superior performance, stability, and simplicity at the positive electrode of PEM electrochemical cells. The structure is based on the development of a stabilized, unique metal sinter that provides PEM fuel cell catalytic activity and facilitates bulk fluid distribution. It will be evaluated in Phase I and implemented in Phase II. The anticipated results are improved bifunctional performance at the positive electrode and similar construction of both the GCI and the bipolar plate, leading to reduced complexity of the system and greater feasibility for a single-unit PEMRFC.

Anticipated Results/Potential Commercial Applications as described by the awardee: The GCI structure will be applicable to dedicated fuel cells and electrolyzers giving improved performance, simplification, and greater reliability. Electrolyzers could supply high-pressure hydrogen to hydrogen/air PEM fuel cells. PEMRFC applications could be particularly important in future development of energy storage or load leveling based on solar energy photovoltaic conversion systems and other advanced low-cost energy conversion concepts (wind power, etc.).

4

Molten Film High-Intensity Paper Drying--Harvest Technology, 14431 Ventura Boulevard, #273, Sherman Oaks, CA 91423-2606; (818) 386-1355
Dr. David Warren, Principal Investigator
Dr. David Warren, Business Official
DOE Grant No. DE-FG03-95ER81982
Amount: $74,993

A novel, energy-efficient, high-intensity drying process will be developed to enhance overall productivity in the paper making operation. The drying process involves direct contact between a wet paper web and a molten metal heat transfer fluid to achieve an order of magnitude increase in the drying rate compared to conventional evaporative dryers. The molten film high-intensity dryer replaces the complex multi-cylinder apparatus and air handling systems of conventional paper dryers with a single, integrated, heat exchange device resulting in a significant reduction in dryer size and cost. Because the high-intensity drying process does not depend on the heating of large quantities of ventilation air to remove moisture from the paper machine room, a 10 to 30% increase in thermal economy is attained. Prior attempts to achieve high-intensity drying using heated belts, platens, or press rolls to transfer drying heat to the paper web have been constrained by limitations in production speed, operating flexibility, and product quality. The use of molten metal alloys as the thermal drying medium overcomes these limitations by providing a simplified dynamic method of high-intensity heat input having relevance to a broad spectrum of drying applications. Phase I will demonstrate the feasibility of the molten film drying cycle, and experimental tests will be conducted to measure heat fluxes and dried paper mechanical properties obtained using a dynamic molten film dryer test rig. Phase II will involve engineering development of the high-intensity molten film dryer to address critical issues for commercial scale-up.

Anticipated Results/Potential Commercial Applications as described by the awardee: Molten film high-intensity drying provides a commercially adaptable method for increasing dryer heat flux, and reduces dryer size, cost and thermal energy consumption. The molten film drying method offers the potential for improved fiber strength and surface properties and is applicable to a wide range of paper related products.

5

Conformal Source Ion Implantation--ISM Technologies, Inc., 9965 Carroll Canyon Road, San Diego, CA 92131-1105; (619) 530-2332
Dr. James R. Treglio, Principal Investigator
Mr. Robert J. Stinner, Business Official
DOE Grant No. DE-FG03-95ER82006
Amount: $74,796

Plasma source ion implantation (PSII) has drawn a great deal of interest as a means of surface modification of large molds and dies. While successful in extending the wear life of such tools and other components, the process has two fundamental drawbacks: no secondary electron suppression, and a high level of dependence on the formation and growth of a plasma sheath. The lack of secondary electron emission leads to extremely high, and very dangerous, levels of X-ray emission and very low system energy efficiency. Inability to control the plasma sheath leads to poor process control. Therefore, the commercial value of the process is greatly limited. This project will develop a variation of PSII, Conformal Source Ion Implantation, or CSII, that will have (1) secondary electron suppression and (2) control of the formation and growth of the plasma sheath. In Phase I, experiments will be conducted on the ability of the CSII concept to suppress emission of secondary electrons. Demonstration of control of formation and growth of the plasma sheath will be left for Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: PSII remains an excellent concept for extending the life of very large molds, particularly for the automobile market. These molds are used to manufacture light weight body parts out of plastics. As the cost of the molds directly impacts the cost of the body parts and the extent of their use, the net effect of PSII would be to lower fuel consumption by lowering the weight of automobiles. By overcoming the primary obstacles to commercial use of PSII, CSII will make these fuel savings a reality.

6

Synthesis and Application of a Novel Electrode Material for Use in Proton-Exchange-Membrane Fuel Cells Capable of Using Simple Organic Fuels and Fuel Reformate--Lynntech, Inc., 7610 Eastmark Drive, Suite 105, College Station, TX 77840-4024; (409) 693-0017
Dr. King Tsai Jeng, Principal Investigator
Dr. Oliver J. Murphy, Business Official
DOE Grant No. DE-FG03-95ER82011
Amount: $75,000

The goal of this Phase I project is to demonstrate the feasibility of using novel electrode materials in proton exchange membrane (PEM)-based fuel cells as versatile power sources. Fuel cells bring about direct conversion of stored chemical energy to electrical energy with efficiencies much higher than those of Carnot engines and with little or no production of pollutants. The PEM-based fuel cell system is one of the leading candidates among fuel cell power sources for many commercial and military applications. Although small organic compounds, such as methanol, formaldehyde, and formic acid as well as fuel reformate, have great potential for use as the main fuels in PEM-based fuel cells, electrocatalyst poisoning makes the use of these compounds impractical. This poisoning is caused by organic intermediates, such as strongly adsorbed carbon monoxide formed during the electrochemical oxidation process. The objective of this project is to synthesize novel poison-resistant electrode materials and to develop methods for their fabrication. The use of such electrode materials in PEM-based organic-air fuel cells will be evaluated to determine their potential in solving electrode poisoning problems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result of this project is the development of poison-resistant, long service life, high energy density, low cost, and more competitive fuel cell power sources. The novel fuel cells can be used as power sources for electric vehicles, small power sources for densely populated regions and remote area applications, portable power sources for communications/news teams, portable power sources for medical instrumentation, and back-up power sources for pulse power supplies.

7

A Steam-Resistant Hydrogen Selective Ceramic Membrane for Fuel Cell Applications--Media and Process Technology, Inc., 1155 William Pitt Way, Pittsburgh, PA 15238-1368; (412) 826-3711
Dr. Paul K. T. Liu, Principal Investigator
Dr. Paul K. T. Liu, Business Official
DOE Grant No. DE-FG02-95ER82021
Amount: $74,684

Fuel cells are theoretically more efficient and produce lower emissions of sulfur oxides and nitrogen oxides than conventional combustion technology for power generation. Although fuel cell technology is commercially available, a number of technical hurdles must be overcome to improve their performance, not the least of which is the economical generation of fuel. A potential source of hydrogen that has been widely investigated is the methane steam reforming process. The production economics can be much improved with the application of advanced membrane reactor technology. Hydrogen selective ceramic membranes would be ideally suited to this application. At the expected reaction temperatures of 450 to 650°C, these membranes display (1) H_2/CH_4 separation factors of 100 to 400, (2) superior H_2 permeance (5 to 10 $m^3/m^2/hr/bar$), and (3) excellent resistance to common natural gas steam impurities (e.g.: sulfur dioxide, hydrogen sulfide). Unfortunately, the hydrogen permeance of these membranes is reduced significantly as a result of sintering by steam at the reaction temperature. Steam-resistant ceramic membrane technology will be explored in Phase I of this project. In addition the potential economic impact will be quantified through mathematical modeling and simulation based upon the experimentally determined hydrogen permselectivity.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful development of the steam-resistant ceramic membrane will reduce both the capital and operating cost of fuel cell technology dramatically. In addition, the membrane thus developed can be used for separations and catalytic membrane reactions in the presence of steam.

8

Silicon Hexaboride Reinforced Aluminum Ingot Material Development for the Transportation Industry--Millennium Materials, Inc., 120 Sherlake Drive, Knoxville, TN 37922-2307; (615) 691-2170
Dr. Samuel C. Weaver, Principal Investigator
Ms. Pamela S. Clabough, Business Official
DOE Grant No. DE-FG02-95ER82030
Amount: $75,000

The high specific strength of metal matrix composites (MMCs) has the potential for reducing vehicle mass, thereby reducing domestic oil consumption. MMCs are of interest for use in brake rotors, calipers, steering knuckles, connecting rods, and other automotive components. Silicon carbide reinforced aluminum (SiC/Al) can be cast, but silicon carbide (3.2 g/cc), which is more dense than molten aluminum (2.4 g/cc), settles to the bottom of the melting crucible. The composite melt requires constant stirring, introducing hydrogen, oxide inclusions, and air bubbles. This Phase I project will develop and produce silicon hexaboride reinforced aluminum (SiB_6/Al) for automotive and other transportation industry applications. The density of silicon hexaboride (2.43 g/cc) is much closer to that of molten aluminum and should have significantly less tendency to settle during the casting operations. Ingots of SiB_6/Al will be manufactured and melted to study the stability of particulate distribution. Test specimens of this new material will be cast and analyzed for physical and mechanical properties. Phase I will be used to define a comprehensive Phase II project which will refine the manufacturing process and produce automotive components for evaluation.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of a high specific strength, readily castable metal matrix composite material holds the potential for reducing vehicle weight and therefore fuel consumption. SiB_6/Al should be much easier to cast than SiC/Al with more uniform particulate distribution and reproducible material properties.

9

Nanostructured Insterstitial Alloys as Catalysts for Direct Energy Applications--Nanomaterials Research Corporation, 10960 North Stallard Place, Tucson, AZ 85737-9527; (602)575-1354
Dr. Tapesh Yadav, Principal Investigator
Dr. Angelo Yializis, Business Official
DOE Grant No. DE-FG03-95ER82034
Amount: $75,000

Interstitial alloys have excellent mechanical properties, thermal properties, and resistance to corrosion. These characteristics and the ready availability of the alloys make them useful in a variety of structural components and cutting tools. These alloys also have unique electronic and magnetic properties that, when combined with their natural mechanical and chemical properties, can lead to commercially useful catalysts with direct energy applications. A particularly significant application of great commercial significance is their potential as replacement catalytic materials for widely-used precious metals such as platinum, iridium, rhodium, and palladium. Not only are precious metals expensive (price ranging from $3,000 to $15,000 per pound), but the United States imports large amounts of these metals to meet the demand for energy and environmental catalysts. Thus, catalysts based on interstitial alloys that can replace precious metals are a significant opportunity. During Phase I, the proof-of-concept that nanostructured interstitial alloys with desirable characteristics can be synthesized will be demonstrated. The catalytic characteristics of the nanostructured interstitial alloys for commercially important reactions will also be evaluated. Phase II will develop, optimize, and field test nanostructured catalysts. Phase III will commercialize the technology.

Anticipated Results/Potential Commercial Applications as described by the awardee: Alloy-based catalysts can help replace precious metals that are presently used in catalysts for energy and environmental applications. This would significantly enhance energy efficiencies, reduce environmental impact, and lower the cost of energy generation and use. The project could also lead to catalysts with unique pathways and enhanced selectivities in commercially useful processes such as hydrogenolysis, isomerization, and hydroprocessing.

10

An Integrated Catalyst/Substrate for Catalytic Combustion--Precision Combustion, Inc., 25 Science Park, New Haven, CT 06511-1968; (203) 786-5215
Dr. William Pfefferle, Principal Investigator
Mr. J. Kevin Burns, Business Official
DOE Grant No. DE-FG02-95ER82055
Amount: $75,000

Catalytic combustion offers significant advantages for high efficiency, ultra-low emissions combustion applications in gas turbine engines, burners, incinerators, and even internal combustion reciprocating engines. With catalytic combustion, nitrogen oxide (NO_x) emissions can be effectively eliminated without aftertreatment by enabling combustion at a temperature below the NO_x formation level. Combustion efficiency is maintained at a high level and carbon monoxide/unburned hydrocarbon emissions are kept low. To date, limits on the ability of the catalyst surface and its substrate to survive high temperatures (e.g., 1000 to 1600°C) in reactive atmospheres have severely restricted practical applications. Body doped, high temperature oxide ceramics such as hexaaluminates offer the promise of a thermally stable, catalytically active monolithic catalyst material through proper choice of host and dopant atoms. This Phase I project will investigate the effects of certain additives to catalytically doped hexaaluminate ceramics for use in catalytic combustion. The catalytic dopants will include platinum and palladium while additives will include catalytically active transition metals and elements which are known to affect the activity of precious metal catalysts when used as substrates.

Anticipated Results/Potential Commercial Applications as described by the awardee: Success would provide a breakthrough for catalytic combustion applications, identifying a class of novel materials and their associated preparation and application techniques suitable for use in advanced catalytic combustors. Such advanced catalytic combustors will have significantly higher efficiencies and lower emissions than currently available technology.

11

A Highly Efficient and Low Emission Catalytic Radiant Burner--Selee Corporation, 700 Shepherd Street, Hendersonville, NC 28792-6472; (704) 697-2411
Mr. David Haack, Principal Investigator
Mr. Kenneth Butcher, Business Official
DOE Grant No. DE-FG02-95ER82067
Amount: $75,000

The objective of this project is to develop catalytic foam radiant burners to replace existing radiant burners. In the past, porous radiant burner technology has been able to improve radiant energy output and reduce nitrogen oxide (NO_X) emissions below 15 ppm compared to conventional burners. Further improvements can be made by incorporating catalysts into the burners. Several catalytic radiant burners have been developed for various industrial applications (e.g., boilers and furnaces). Although the combustion performances of these burners are impressive, low lifetimes of combustion catalysts and burner substrates make them less attractive and keep them from being introduced to the market. Currently, several problems associated with existing catalytic radiant burners have been overcome by a unique foam radiant burner design. In this Phase I project, a new family of near-zero thermal expansion materials (e.g., sodium zirconium phosphates and their composites) will be used to prepare burner substrates. These burner substrates will be further coated with high temperature combustion catalysts. Foam radiant burners with various compositions and pore sizes will be fabricated. The effects of material composition and preparation process of porous foam on the combustion performance of the catalytic foam radiant burners will be examined. In Phase II, the catalytic foam radiant burners will be fabricated into a pilot scale.

Anticipated Results/Potential Commercial Applications as described by the awardee: The results should demonstrate the economic and environmental benefits of using the new catalytic radiant burners to replace existing radiant burners. The potential commercial applications of this technology include boilers and water heaters, paint drying, pulp and paper drying, metal and plastic coating, and volatile organic compound incineration.

12

Light Emitting Devices Based on Germanium Quantum Crystals in a Direct Bandgap Matrix (Aluminum Nitride)--Structured Materials Industries, Inc., 120 Centennial Avenue, Piscataway, NJ 08854-3908; (908) 885-5909
Dr. Gary S. Tompa, Principal Investigator
Dr. Gary S. Tompa, Business Official
DOE Grant No. DE-FG02-95ER82080
Amount: $74,995

Recent observations of photo emission and absorption in nanoparticle material systems has strengthened the theory that the optical properties of nanocrystals can be drastically altered by quantum size effects. Such quantum effects have been demonstrated by observing white light electroluminescence and photoluminescence (from the infrared, through the visible, to the ultraviolet) in chemical-vapor-deposition-deposited thin films. These thin films have consisted of silicon (Si) and germanium (Ge) "quantum" crystals (QCs) embedded in a silicon dioxide (SiO_2) matrix. Alternatively, this project will develop electroluminescent devices based on Ge QCs embedded in aluminum nitride (AlN) films. The films will be formed by a unique ion beam assisted deposition process that has previously been used to deposit AlN films and shown to be compatible with large area processing. The advantage of the AlN host matrix is that the AlN can be doped n type and potentially p type, which will allow the fabrication of Ge QC electroluminescent devices containing p-n junctions in the AlN-AlN or AlN-substrate structures. P-n junctions cannot be simply fabricated with SiO_2 host matrix films. It is expected that the direct bandgap and dopable AlN host matrix films will be an excellent alternative for high performance emitters and ultimately quantum crystal display applications. In Phase I, metal-insulator-semiconductor (MIS) structures will be fabricated using AlN films containing Ge QCs. Feasibility of the QC concept in this material system will be shown by demonstrating visible electroluminescent emission from AlN-based devices. In Phase II, full color (white) electroluminescent films for light-emitting diodes (LEDs) and displays based on MIS will be developed, and p-n junction devices will be fabricated from these QC films.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of QC material systems has important applications in LEDs, displays, and sensor arrays for infrared, visible and ultraviolet applications. Other applications of the QC material system include solar cells, laser dyes, field emitters, and phosphors. Each of these applications represents significant markets.

13

Low Cost, Novel Precursors to Beta" Alumina Solid Electrolyte--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033-1916; (303) 940-2301
Dr. Ronald Cook, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-95ER82087
Amount: $75,000

Advanced, high energy and high power density batteries such as the sodium sulfur or the sodium metal chloride batteries use Beta" alumina, a fast sodium ion conductor, as the solid electrolyte. Unfortunately, the development and commercialization of these batteries has been hindered by problems with reliability of the Beta" alumina. Conventional ceramic processing of Beta" alumina is based on a solid state reaction between alpha alumina, sodium oxide and lithium oxide. The reaction requires high sintering temperatures and can lead to undesirable microstructures with poor mechanical properties. Improved processing should lead to a material with higher density higher fracture toughness, and improved control over grain size should improve the reliability of the Beta" alumina. Previously, an improved, low-cost route to Beta" alumina has been identified that has the potential to lower the sintering temperature, allow easier formability, and yield dense, high conductive polycrystalline material. In Phase I, samples of Beta" alumina will be prepared through the new process in the form of disks and tubes. The electrochemical properties and microstructure of the materials will be characterized, and an engineering analysis will be carried out to compare the cost/performance of the new process to conventional methods.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of the Phase I will lead to the development of a low cost process for the production of Beta" alumina ceramic. Beta" alumina finds application as a solid electrolyte in high temperature, high performance batteries, and this new process could also lead to the synthesis of new materials based on Beta" alumina such as mixed ionic-electronic conductors and optical materials (e.g., host materials for solid-state lasers).

14

A Nanolayer Coating for Dry Machining--Technology Assessment & Transfer, Inc., 133 Defense Highway, Suite 212, Annapolis, MD 21401-7015; (301) 261-8373
Dr. David Crowther, Principal Investigator
Mrs. Sharon Fehrenbacher, Business Official
DOE Grant No. DE-FG02-95ER82093
Amount: $74,761

Pending OSHA and EPA legislation is increasing the pressure on industrial and government facilities to reduce the worker safety hazards of cutting fluids. Therefore, coatings capable of high-speed, dry machining offer billions of dollars savings in energy and environmental costs. This project will demonstrate the feasibility of magnetron sputtered coatings of novel material combinations and structures for dry machining. In Phase I, hard material systems with attractive high temperature properties will be coated. Laboratory scale measurements of adhesion hardness, toughness, abrasion, friction, and wear, will be conducted, followed by coated insert turning tests. Feedback from the material property measurements and turning tests will provide guidance for the compositional and processing refinements for coating specific classes of materials, such as cast iron, high alloy steels, aluminum and titanium.

Anticipated Results/Potential Commercial Applications as described by the awardee: Advanced coatings for dry machining could provide an enormous productivity boost for the more than 100,000 U.S. machining facilities. Extensive spinoff potential exists for a host of tribological applications in the aerospace, automotive, chemical, energy, textile, and metal forming industries.

ADVANCED INSTRUMENTATION TO EXPLOIT NEUTRON AND PHOTON SOURCES

15

A Two Dimensional Semiconductor Imaging Array for Scattered Cold Neutrons--Intraspec, Inc., P.O. Box 4579, Oak Ridge, TN 37831-4579; (615) 483-1859
Mr. John Walter, Principal Investigator
Mr. John Walter, Business Official
DOE Grant No. DE-FG02-95ER82004
Amount: $75,000

With the advent of stronger sources of cold neutrons, there is a need for much faster response of imaging arrays. Existing two dimensional wire arrays are limited to about 40,000 counts/sec with 10% dead time and are handicapped by ghost images resulting from pile-up problems. Ratios greater than 10,000 in the count rate between peak and normal rates are needed in many experiments. There is also a need for curved detectors which is impractical with stretched-wire detectors. By combining silicon (Si) detector pixel sub-arrays (seven cm square with five mm square pixels) with a neutron-to-charged-particle convertor, substantially spherical array systems would be possible with good efficiency, very high count rate capability, and low image distortion from pile-up. The goal of this research is to demonstrate the feasibility of a $>10^4$ pixel array (made up of 196 element sub-arrays) which provides high rate detection and data collection for the angular distribution of low-energy neutrons scattered during structure studies. The objectives of Phase I are to: (1) confirm the technical feasibility of an Si pixel sub-array for high count rate, (2) obtain low cross talk cold neutron imaging with reasonable detection efficiency, and (3) estimate the development and manufacturing costs for a 0.5 m square array made up of 49 sub-arrays (9,604 pixels). These sub-arrays will be combined into a large imaging array.

Anticipated Results/Potential Commercial Applications as described by the awardee: The final result should allow a revolutionary improvement in neutron structure studies. It also could open new possibilities in other research involving detector arrays and in replacement of discrete-component signal conditioning chains with monolithic chips. The instruments would be able to handle very high rates without the usual problems of pile-up induced ghost images. The technology developed will also prove useful for other applications such as particle physics arrays and x-ray imaging.

16

A Thermal Neutron Detector Based Upon a Lanthanum Boron Germanate Scintillator--Mission Support, Inc., P.O. Box 511283, Salt Lake City, UT 84151-1283; (801) 773-7900
Dr. J. Bart Czirr, Principal Investigator
Mr. David B. Merrill, Business Official
DOE Grant No. DE-FG03-95ER82032
Amount: $74,947

This project will develop a new class of thermal neutron detectors based upon cerium-activated borate single-crystal scintillators. Thermal-neutron capture in the ^{10}B contained in the crystal will yield a charged-particle signal and a 478 keV gamma ray that will be utilized to provide a coincidence signal. This dual-signal technique will be used to discriminate against gamma-ray backgrounds. The goal of the Phase I project is to discover the most efficient boron-containing inorganic scintillator material and to develop production techniques that will yield full-scale detectors. If successful, these detectors will provide a significant increase in data quality and quantity over that obtainable from existing systems used at neutron scattering facilities in the United States and internationally.

Anticipated Results/Potential Commercial Applications as described by the awardee: An efficient boron containing scintillator material will yield lower background levels compared to existing solid-state detectors and increased data rates relative gaseous detectors used at neutron scattering facilities.

17

Advanced Silicon Carbide and Beryllium/ Aluminum Alloy Integrally Cooled X-ray Synchrotron Mirrors--SSG, Inc., 150 Bear Hill Road, Waltham, MA 02154-6397; 617-890-0204
Mr. Michael I. Anapol, Principal Investigator
Mr. Dexter Wang, Business Official
DOE Grant No. DE-FG02-95ER82074
Amount: $74,992

Due to recent advances in synchrotron radiation sources, beamline optics have emerged as a major limitation on beam brilliance at the sample. Advanced high-heat-load, x-ray mirror design and fabrication techniques combined with innovative thermal management schemes must be developed and proven under synchrotron operating conditions. This project will explore: (1) two new substrates materials, silicon carbide (SiC) and a beryllium aluminum (Be/Al) alloy, which offer superior thermal stability and mechanical properties; (2) enhanced cooling techniques (e.g., cryogenic cooling, two-phase flow, subcooled binding, phase change coolants, liquid metal cooling) with improved heat transfer coefficient and heat removal efficiency; (3) advanced reflective multilayer coating, derived from Department of Defense nuclear hardened and high energy laser technologies; (4) lower cost substrate fabrication (casting and performing to near net shape with integral cooling channels); and (5) rapid optical surfacing (diamond turning, and direct replication for figure control). The Phase I effort will demonstrate the feasibility of SiC and/or Be/Al x-ray mirror technology combined with thermal management for a small (10 cm) beamline mirror under simulated beamline conditions. Phase II will extend the development to a prototype beamline mirror(s) (20 to 50 cm) to be incorporated into a high energy synchrotron facility.

Anticipated Results/Potential Commercial Applications as described by the awardee: The results of the project will benefit synchrotron users. The technology also applies to NASA and NSF x-ray space experiments and Department of Defense applications. X-ray lithography is an emerging technology over the next five years which represents a multi-billion dollar potential market.

CERAMIC FIBERS AND FIBER COATINGS FOR HIGH TEMPERATURE APPLICATIONS

18

Pseudo-Porous Zirconium Carbide Fiber Coating for Environmentally Durable Silicon Carbide/Silicon Carbide Composites--Hyper-Therm High-Temperature Composites, Inc., 18411 Gothard Street, Units B and C, Huntington Beach, CA 92648-1235; (714) 375-4085
Dr. Robert J. Shinavski, Principal Investigator
Mr. Wayne S. Steffer, Business Official
DOE Grant No. DE-FG03-95ER81985
Amount: $68,955

Ceramic-matrix composites (CMCs) are being actively developed for a variety of high temperature aerospace, industrial and energy-related applications. While possessing high specific strength and stiffness, and high fracture toughness, current CMCs are severely limited by their susceptibility to oxidation embrittlement and strength degradation when stressed at or beyond the matrix cracking stress point and subsequently exposed to high temperature oxidation. This time-related deterioration of properties is related to the thermal and/or environmental instability of fiber coatings used to control the fiber/matrix interface. The designed properties of the interface that result in crack deflection and fiber pull-out must be maintained to give CMCs their tough behavior. In Phase I, this project will develop and evaluate a fiber coating that maintains its designed properties after long-term exposure to high temperature oxidation. The proposed fiber coating is a pseudoporous zirconium carbide fabricated by chemical vapor deposition methods. Although this material alone has poor oxidation resistance, once it is oxidized, a truly porous zirconia interphase will be left behind. By controlling the initial level of pseudo-porosity in the deposited fiber coating, the level of porosity within the stable zirconia interphase can be controlled. This interphase will provide the necessary weak, compliant interlayer necessary for good mechanical properties. It will also separate the silica layer formed on the surface of the fiber and matrix in silicon carbide/silicon carbide (SiC/SiC) composites that results in oxidation embrittlement if the interphase is bridged by the silica scales. SiC/SiC composite panels incorporating three different levels of pseudoporous ZrC and one baseline pyrolytic carbon fiber coating will be produced. Tensile stress-strain and fracture toughness characteristics will be determined at room temperature, following high temperature isothermal conditioning in air, and in post-stressed oxidation environments. Microanalysis will be used to trace the evolution of the pseudoporous ZrC into a stable porous zirconia interface.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of an environmentally durable CMC is critical to the widespread application of these materials in power generation components such as heat exchangers, combustor liners, and other high temperature structural components that would result in increased efficiency, reduced emissions, and subsequently lower operating costs. Many additional applications exist in the aerospace and defense industries such as hypersonic airframe thermal protection systems, aerospace propulsion combustors, and reusable nozzles.

19

Controlled Shear Strength Oxidation-Resistant Interfacial Coatings--Ultramet, 12173 Montague Street, Pacoima, CA 91331-2210; 818-899-0236
Dr. Arthur J. Fortini, Principal Investigator
Mr. Craig N. Ward, Business Official
DOE Grant No. DE-FG03-95ER82100
Amount: $74,984

Fiber-reinforced ceramics represent an enabling technology for the next generation of aircraft engines and power generating equipment. For use in oxidizing environments, the current state of the art in ceramic matrix composites (CMC) is a silicon carbide (SiC) matrix material reinforced with low-oxygen Nicalon (SiC) fibers. Both components exhibit good oxidation resistance. However, the interfacial materials currently used, boron nitride and pyrolytic carbon, have very poor oxidation resistance at temperatures above approximately 800° and 600°C, respectively. When used in a high temperature oxidizing environment, the interfacial coatings are severely attacked, thereby causing the mechanical properties of the composite to be degraded. In this Phase I project, an oxidation-resistant interfacial coating system will be developed that will allow CMCs to be used in aggressive, oxidizing atmospheres. The coating will not only provide the necessary weak bond between the fibers and the matrix, but it will also be chemically compatible with both the fibers and the matrix at elevated temperatures.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful development of oxidation-resistant, controlled shear strength interfacial coatings will enable the use of CMC materials in a wide range of applications, from commercial and military turbojet engines to power generating and industrial processing equipment.

CHEMICAL SCIENCES RESEARCH

20

A New Type of Acoustical Sensor for Chemical Measurements--Analysis Consultants, 21831 Zuni Drive, Lake Forest, CA 92630-3553; (714) 830-1033
Dr. B. G. Martin, Principal Investigator
Dr. B. G. Martin, Business Official
DOE Grant No. DE-FG03-95ER81922
Amount: $75,000

This project involves an entirely new sensor concept for monitoring the presence, concentration, and reactions of a wide variety of chemical species, including organic solvents, salts, and biological chemicals. This sensor design exploits the acoustical properties of symmetric multilayers placed on a piezoelectric transducer. These properties are extremely sensitive to changes in layer density, thickness, and elastic constants, all of which are functions of the molecular state. The symmetric multilayer materials used would be a class of bioelastic polymers which are capable of converting many forms of chemical reaction energy into changes affecting the molecular state. The major advantages of the planned sensor are its sensitivity, versatility, and chemical specificity. The Phase I effort will be to design, fabricate, and test a prototype sensor utilizing bioelastic polymeric materials. This would involve the selection of a polymer for a specific chemical reaction, e.g., one that is pH sensitive, or one that is sensitive to the presence of a salt or an organic solvent.

Anticipated Results/Potential Commercial Applications as described by the awardee: The outcome of this project should be a new type of acoustical sensor which utilizes bioelastic polymers for a wide variety of chemical measurements. The device would be inexpensive, rugged, and capable of in-situ chemical monitoring in a non-laboratory environment.

21

Chemically Resistant Gas Separation Perfluoromembranes--Compact Membrane Systems, Inc., 325 Hampton Road, Wilmington, DE 19803-2425; (610) 499-8860
Dr. Stuart Nemser, Principal Investigator
Dr. Stuart Nemser, Business Official
DOE Grant No. DE-FG02-95ER81942
Amount: $75,000

Current membranes for gas separation are based on organic polymerics. These organic polymers have significant temperature and chemical limitations which limit their usage in the chemical process industry (CPI). This project focuses on developing high temperature, chemically stable, high gas flux perfluoromembranes for usage in harsh (chemical, temperature) environments consistent with existing needs in the CPI. In Phase I, high flux thin perfluoropolymer films will be fabricated on chemically resistant porous supports. Single gas testing of perfluoromembranes will initially be done using harsh gases and appropriate secondary gases. This will be followed by single gas evaluation of thin film perfluoromembranes and then by evaluation of mixed gases on these membranes. The Phase I project will focus on chlorine and hydrogen separations associated with the chlor-alkali industry with care taken to avoid explosive conditions. Engineering simulations will be done in parallel to actual tests. In Phase II these units will be scaled up for pilot testing in the chlor-alkali industry and other harsh chemical separations.

Anticipated Results/Potential Commercial Applications as described by the awardee: These fluoropolymers in combination with existing thin film processes and chemically resistant porous supports should significantly expand the usage of membranes for a range of applications in CPI. Key commercial applications include halogen separations including chlor-alkali industry hydrogen/chlorine separations and fluorochemistry processes using hydroflouric acid.

22

A Miniature Multi-Chemical Sensor Using Micro-Cantilevers--Consultec Scientific, Inc., 725 Pellissippi Parkway, Suite 110, Knoxville, TN 37932-3300; (615) 675-4333
Dr. Scott R. Hunter, Principal Investigator
Mr. John D. Morris, Business Official
DOE Grant No. DE-FG02-95ER81943
Amount: $75,000

This project will result in the development of a revolutionary class of miniature chemical sensors that are as much as 1000 times more sensitive, up to 1000 times smaller, and considerably less expensive than currently available multichemical sensors. This will be achieved by utilizing microcantilever technology, such as that commonly used in scanning force microscopy. Both the resonance frequency and the bending of these microcantilevers have been shown to vary reproducibly and sensitively (with picogram to sub-picogram sensitivity) as a consequence of adsorption of molecules on their surfaces. In preliminary studies, it has been shown that these microcantilevers can be used to detect a variety of chemicals, ranging from aromatic hydrocarbons and alkyl mercaptans to mercury vapor. Analyte-selective coating of the surface of individual microcantilevers provides specificity for target species. This basic concept will be extended during Phase I to demonstrate detection and identification of key components in a mixture, using multiple coated microcantilevers and pattern recognition analysis. Because numerous microcantilevers may be packaged into an extremely small volume, localized sensing and nearly instantaneous response are facilitated with this approach. Also, the monolithic nature of potential multichemical sensors should minimize sensitivity to extreme temperature or pressure changes by assuring that all active and reference sensor elements are in equilibrium with the same monitored environment. Phase I efforts will be limited to a proof-of-principle demonstration for a limited range of analytes. Once demonstrated, however, extension to numerous other analyte and sample matrix systems can be effected by a change in coating set. Hence, the planned work will provide a highly significant advance in sensor technology with possibilities of developing new sensors for other chemicals.

Anticipated Results/Potential Commercial Applications as described by the awardee: Commercial applications of miniature multichemical sensors are numerous since they offer extremely high sensitivity, are easily miniaturized, and could be readily mass produced. The inexpensive chemical sensors resulting form this effort should have use in high volume commercial applications in many areas, including industrial process monitoring, air and water pollution control, air quality monitoring, and vehicle emission monitoring.

23

High Capacity Carbon Anodes for Lithium Ion Batteries--EIC Laboratories, Inc., 111 Downey Street, Norwood, MA 02062-2668; (617) 769-9450
Dr. K. M. Abraham, Principal Investigator
Dr. A. C. Makrides, Business Official
DOE Grant No. DE-FG02-95ER81959
Amount: $74,500

The proliferation in recent years of electronic and portable devices of ever-decreasing sizes and weights has spurred the demand for high energy density rechargeable batteries. Lithium (Li) ion batteries can play a major role in fulfilling this need. The unavailability of high capacity carbon anodes, however, has limited the energy density of these batteries. Research to develop a novel high capacity carbon anode suitable for rechargeable Li ion batteries is planned. In Phase I, a fundamental understanding of the structure-property relations of the carbon will be determined. Experimental conditions leading to a material with the best overall performance of capacity, rate, and rechargeability will be identified. Phase I tasks will include: (1) preparation of carbonaceous materials, (2) characterization of the carbons, and (3) electrochemical evaluation of the carbons in Li cells.

Anticipated Results/Potential Commercial Applications as described by the awardee: Rechargeable Li ion batteries based on this high-capacity carbon anode will possess high energy densities, long-cycle life, and high safety. They are expected to find applications in portable consumer devices such as cellular phones, camcorders, pagers, computers, and electric tools.

24

Advanced Chemiresistor Devices as Micron Size Sensors for the Rapid, On-Line Measurement of Chemical Vapors--Microsensor Systems, Inc., 62 Corporate Court, Bowling Green, KY 42103-7023; (502) 745-0099
Dr. Hank Wohltjen, Principal Investigator
Dr. Hank Wohltjen, Business Official
DOE Grant No. DE-FG02-95ER82028
Amount: $73,005

An advanced chemical microsensor with potential for highly localized (micron-size scale) sensing is planned as a rapid response, in-situ chemical vapor detector for chemical process monitoring. Such chemical microsensors will be of considerable value for the real-time monitoring of manufacturing processes and detecting changes in the composition of chemical waste streams. The new sensors are based on the incorporation of small concentrations of conducting particles in polymer matrices to form chemically sensitive semiconductors. When exposed to chemical vapors that are specifically absorbed by the polymer, the matrix will swell and change the particle contact geometries and interparticle distances, thus increasing the electrical resistance. Thin, uniform layers of polymer/metal mixtures can be formed on very small quartz or alumina substrates etched with a laser beam. Long, narrow serpentine lines with length-to-width ratios greater than 1000 to 1 can be formed, allowing device sensitivities at the parts per billion level. Among the advantages of polymer/metal chemiresistors is that their size can be reduced to micron-size dimensions using standard planar electronic microfabrication technology. Such devices will require minimal electronic circuitry for operation and can be readily installed in a chemical vapor stream where they will respond rapidly to small changes in chemical composition and concentration. Also, they will operate at high pressures, consume very little power, and be very inexpensive. Phase I will determine the overall feasibility of the approach. Different polymer/metal particle combinations, as well as the level of particle loading, will be examined. Sensitivity response time and selectivity will be examined for the selected polymer/metal combinations.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that polymer/metal chemiresistor microsensors will have a very high sensitivity and a rapid response to chemical vapors. They will operate at high pressures and at temperatures limited by the polymer matrix used. Because they are also very small, rugged, of low cost, and require simple electronics, they should be well suited for application as on-line sensors in industrial processes and as long-term continuous monitors for hazardous waste sites.

HIGH TEMPERATURE SUPERCONDUCTIVITY FOR ENERGY APPLICATIONS

25

A Low Cost, High Temperature Superconductor Wire Manufacturing Technology--American Superconductor Corporation, 2 Technology Drive, Westborough, MA 01581-1799; (508) 836-4200
Mr. Lawrence J. Masur, Principal Investigator
Mr. Ramesh Ratan, Business Official
DOE Grant No. DE-FG02-95ER81919
Amount: $75,000

This project will establish the feasibility of an economical, long length (greater than 50 km) process for manufacturing high temperature superconducting (HTS) wires. DOE has issued a cost goal of $10/kA-m, which is close to the cost of present low temperature superconductivity (LTS) technology (present costs for state-of-the-art niobium tin wires are $4 to $12/kA-m, depending on the temperature of application). Experience from LTS technology indicates that cost/performance will ultimately distinguish between commercial success and failure Hence, to be commercially successful, the cost/performance of HTS wires must be competitive with that of LTS wires. Experience from the LTS technology also indicates that the DOE cost goal can only be met with a manufacturing technology that is readily scalable to long, continuous lengths. The metallic precursor process, developed for the economical production of HTS wires, has the potential to meet the DOE cost goal. However, a critical process step is still absent which prevents the scale-up of the process to long, continuous lengths. An innovative solution to the critical problem of scaling up the metallic precursor process to continuous lengths of up to 50 km is being planned. Presently, the continuous wire length achievable with the metallic precursor process is limited to less than one km, principally because of the limits imposed by billet extrusion. The Phase I project will eliminate the length limitation by identifying deformation processing modes and conditions that enable metal working processes for large volume production of HTS wires. Phase I will employ an innovative marriage of metal working technology with the metallic precursor process.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project should result in a cost-effective manufacturing process for HTS wires which will meet the DOE cost/performance metric of $10/kA-m. The fabrication of cost-effective HTS wire will allow commercial production of viable subsystems, enabling economical production of HTS components for the power generation, power transmissions, and power end-user electric motor markets.

26

Development of a Process Management Technology for the Manufacture of High Temperature Superconductors to Improve Conductor Quality--American Superconductor Corporation, 2 Technology Drive, Westborough, MA 01581-1799; (508) 836-4200
Mr. David M. Buczek, Principal Investigator
Mr. Ramesh Ratan, Business Official
DOE Grant No. DE-FG02-95ER81917
Amount: $75,000

Recently, remarkable progress has been made in extending the electrical, mechanical, and environmental durability of high temperature superconductors (HTS), bismuth strontium calcium copper ($Bi_2Sr_2Ca_2Cu_3$) phase, to useful and desirable long length configurations. However, as HTS technology is incorporated into commercial products (motors, generators, current limiters, and transmission lines), stiff global competition will be assured. This challenge is being addressed in Phase I by the development of a manufacturing database to better understand the process variables and their relationship to measurable process parameters and to the final HTS characteristics. The critical process variables for optimization will be identified, and the quality controls to be used in full scale manufacturing will be established. A manufacturing database design will be developed to statistically analyze process data. This will allow for the identification of key intermediate steps with critical process outputs that affect final superconducting performance characteristics. In Phase II, ruggedness experiments will be performed to improve the quality of the manufacturing process, and quality procedures will be developed to control critical manufacturing steps.

Anticipated Results/Potential Commercial Applications as described by the awardee: Product quality, as demonstrated by foreign competitors, is greatly influenced by the interaction of research and development, engineering, and manufacturing during the product development stage. A thorough understanding of process technology and variables, and their interaction with the final outcome is essential in insuring a cost effective transition into full scale production.

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High Current Density High Temperature Superconductor Composite Conductors--American Superconductor Corporation, 2 Technology Drive, Westborough, MA 01581-1799; (508) 836-4200
Dr. Martin W. Rupich, Principal Investigator
Mr. Ramesh Ratan, Business Official
DOE Grant No. DE-FG02-95ER81918
Amount: $75,000

The economical development of high temperature superconductors for a wide range of commercial and military applications will require current densities approaching 10^5 A/cm^2, well above the present levels of practical conductors. Attaining these levels requires innovative approaches to utilize the full capabilities of the present HTS materials. This project will develop a multifilamentary composite conductor made up of bismuth, strontium, calcium, copper, and oxygen (commonly referred to as "BISCO"), with the designation Bi-2223, that will achieve these required current densities and also have mechanical properties and alternating current

(AC) performance. The planned study is based on a composite conductor containing hundreds to thousands of ultrafine Bi-2223 filaments. The composite design and performance will be demonstrated in Phase I through the use of improved precursor powders and novel deformation techniques. The ultimate goal of Phase II is the development of the innovative composite design into a long length conductor using a manufacturable process that can be integrated into a long length HTS conductor production process.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of practical composite conductors with significant improvements in current density, mechanical properties, and AC performance will allow the development of HTS applications that are economically competitive with conventional devices. Specific applications that will be of benefit include power transmission cables, motors, generators, superconducting magnetic energy storage, current limiters, and transformers. The commercialization of HTS will result in significant energy savings and the development of new technologies and manufacturing jobs.

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Superconducting Wires for Alternating Current Magnet Applications--American Superconductor Corporation, 2 Technology Drive, Westborough, MA 01581-1799; (508) 836-4200
Dr. Alex Otto, Principal Investigator
Mr. Ramesh Ratan, Business Official
DOE Grant No. DE-FG02-95ER81920
Amount: $75,000

The majority of promising high temperature superconducting wire magnet applications will operate under complete or ripple AC conditions, where AC loss mechanisms dissipate energy well before the DC critical current of the superconductor is reached. The low inductance requirements of these applications also requires high current cabled conductors. Past development has been focused on flat tapes containing bismuth, strontium, calcium, copper, and oxygen (called Bi-2223 oxide) superconductor that, although exhibiting high current densities at DC conditions, pose daunting problems with cabling and AC losses. In low critical temperature processing, for example, only low aspect ratio multifilamentary wires have been successfully cabled with acceptably low losses for AC magnets. This project will establish the feasibility of a process for manufacturing high current, low aspect ratio superconducting wires suitable for cabling and use above 20 K in alternating current (AC) magnet applications. Phase I of this project will develop a deformation process for attaining transport properties in low-aspect-ratio, multifilamentary, Bi-2223 oxide-silver composite wire made from metallic precursors with transport properties comparable to flat tapes. The project will then demonstrate the feasibility of cabling these wires such that these transport properties are maintained in the cables.

Anticipated Results/Potential Commercial Applications as described by the awardee: This basis for manufacturing superconducting wire suitable for cabled conductors in AC magnets operating above 20 K will enable the development of large markets for high temperature superconductors in AC superconducting magnet applications.

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A Resistive Fault Current Limiter Based on Highly Directional Superconductor Thick Film Conductors--Illinois Superconductor Corporation, 451 Kingston Court, Mount Prospect, IL 60056-6068; (708) 391-9400
Dr. James D. Hodge, Principal Investigator
Ms. Ora Smith, Business Official
DOE Grant No. DE-FG02-95ER81994
Amount: $74,953

This project will develop a high power fault current limiter device based upon highly directional thick film conductors. The feasibility of resistive fault current limiters based on high temperature superconductors has been demonstrated. However, to extend this technology to the higher current levels required by utility and industrial applications (600 to 3000 A), high current density conductors will be required. Higher current densities will, in turn, require that greater amounts of joule heating be dissipated during a fault. This project will address both of these issues by fabricating a directionally solidified thick film conductor. The project will utilize unique controlled thermal gradient processing technology to produce highly oriented bismuth strontium calcium copper oxide ($Bi_2Sr_2CaCu_2O_x$) or yttrium barium copper oxide ($YBa_2Cu_3O_{7-x}$) thick films on substrates appropriate for the application, i.e., negligible electrical conductivity, high specific heat, and high thermal conductivity. During Phase I, sample conductors will be produced to demonstrate the feasibility of the directionally recrystallized thick film technique, while Phase II will focus on the fabrication of a demonstration prototype utilizing these conductors.

Anticipated Results/Potential Commercial Applications as described by the awardee: The feasibility of the textured thick film approach to fabricating a resistive fault current limiter will be demonstrated and a proof-of-concept prototype device will be subsequently fabricated. The successful demonstration of this device will, in turn, lead to the manufacturing scale-up to produce commercial devices for sale into the utility or industrial power system marketplace.

30

A Low Cost, Windable Yttrium-Barium-Copper-Oxide Conductor by Continuous Ion Beam Assisted Deposition/Metal Organic Chemical Vapor Deposition on a Metallic Substrate Tape--Intermagnetics General Corporation, 450 Old Niskayuna Road, Latham, NY 12110-0461; (518) 782-1122
Dr. Michael S. Walker, Principal Investigator
Mr. Carl H. Rosner, Business Official
DOE Grant No. DE-FG02-95ER82000
Amount: $74,921

Yttrium-barium-copper-oxide (YBCO) is the most attractive of the high temperature superconductor materials for magnet and power applications. It will operate in liquid nitrogen at 77 K. (Low temperature superconductors, by contrast, operate at a maximum of about 10 K.) Until recently, all efforts to make practical conductors of YBCO material to carry current over long lengths have been frustrated by grain boundary "weak links" which severely limit the critical current in the presence of a magnetic field. A new technical approach has allowed the coating of flexible metallic substrates with YBCO of sufficiently high quality to make a practical conductor. The key to this process is the ion-beam-assisted-deposition (IBAD) of a highly textured thin- film buffered layer onto the substrate. Subsequent thick deposits of YBCO are orientated by the buffered layer and carry practical levels of current at 77 K. The IBAD-buffered substrate layer may be extremely thin, making its manufacture amenable to scale-up of the present process. YBCO coatings may need to be as thick as five or ten microns, however, requiring higher rate YBCO deposition methods. Metal organic chemical vapor deposition (MOCVD) has proven its capability for the manufacture of long lengths of YBCO tape conductor. Phase I is intended to demonstrate the basic IBAD/MOCVD compatibility and to achieve practical levels of surface current.

Anticipated Results/Potential Commercial Applications as described by the awardee: This low-cost, high-field 77 K conductor would enable a reduction in size and weight and an increase in the efficiency of generators, motors, transformers, transmission lines, magnetic energy storage, and specialty magnets for many of applications. Whatever is being developed now with low temperature superconductors can be vastly improved with YBCO. Many tens of billions of dollars in energy savings to the Nation are projected for the use of this conductor in commercial applications.

31

An In-Process Quality Monitoring System for High Temperature Superconducting Wire Manufacturing--Quality Engineering Associates, Inc., 25 Adams Street, Burlington, MA 01803-4915; (617) 221-0080
Dr. Ming-Kai Tse, Principal Investigator
Dr. Ming-Kai Tse, Business Official
DOE Grant No. DE-FG02-95ER82056
Amount: $75,000

This research is directed towards the development of an in-process quality monitoring system for the manufacture of high temperature superconducting (HTS) wires. Significant technical barriers must be overcome in order to achieve the tremendous market potential of HTS products. A specific goal is the production of long (> one km) HTS wires with a high critical current density that can be operated at high temperature and high magnetic field. An enabling technology to produce such long, high performance HTS wires is a quality monitoring and control system that can be used to evaluate wire quality

in-process. With such a system, wire defects can be detected and quantified as the wire is being produced. Such an on-line detection and process control scheme can improve wire quality and reduce manufacturing cost. In Phase I, the feasibility of an eddy current nondestructive testing technique for HTS wire monitoring will be investigated and the design criteria for a practical system will be established. Similar technology has been successfully demonstrated in the manufacture of low temperature niobium-titanium superconducting wires.

Anticipated Results/Potential Commercial Applications as described by the awardee: This research will establish the feasibility of a critical enabling technology for the manufacture of HTS wires. This technology is vital to the advancement of high temperature superconductivity into wide spread commercial applications. The most significant contributions of this technology will be quality assurance and reduction of manufacturing costs.

IMPROVED MATERIALS FOR THE PULP AND PAPER INDUSTRY

32

A New Alloy for Refiner Plates in the Pulp and Paper Industry--Climax Research Services, 39205 Country Club Drive, Suite C-40, Farmington Hills, MI 48331-3495; (810) 489-0720
Mr. Richard B. Gundlach, Principal Investigator
Mr. James R. Lakin, Business Official
DOE Grant No. DE-FG02-95ER81940
Amount: $75,000

The pulp and paper industry has identified an economic advantage to operating thermomechanical pulping units at higher speeds which would make more efficient use of electric power in pulp mill operation. Pilot plant studies have shown that increasing the speed of wood grinding discs in a double-disc pulp refiner from 1200 rpm to 1800 rpm reduced energy costs by 20% while maintaining the fiber quality of the pulp produced. In addition to this energy saving, the U.S. papermaking industry has a general need for improved pulp refiner grinding disc alloys with increased life at higher operating speeds. This Phase I project will develop a new high-chromium iron alloy with properties tailored specifically to pulp refiner plate applications. Non-conventional abrasive carbide phases will be used in the refiner alloy. The new high-chromium iron alloy will have improved wear resistance, corrosion-abrasion and cavitation-erosion resistance, and impact resistance. As a measure of fracture toughness, the new iron alloy compositions will be cast and tested under conditions of abrasive wear, corrosion-abrasion and cavitation-erosion in aqueous pulping water, and dead-weight impact. The test data will be analyzed, and an optimal alloy composition will be established with properties superior to those of conventional pulp refiner alloys. This will be the first step of an alloy optimization program in a Phase II study. Castings of this improved composition will be evaluated, and the potential of the new alloy for commercial pulp refiner plate use will be determined.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned research should result in the development of a new high- chromium iron alloy tailored specifically for pulp refiner plate applications in the pulp and paper industry. It will possess the range of metallurgical, mechanical, and physical properties required by refiner plate manufacturers for alloys for use in both conventional and high speed refining. These properties will guarantee its rapid introductions into refiner service in pulp mills.

33

Development of Novel Iron-Chromium-Silicon Alloys for Use in Kraft Recovery Boilers--E. R. Johnson Associates, Inc., 9302 Lee Highway, Suite 700, Fairfax, VA 22031-1214; (703) 359-9355
Dr. Mark A. Harper, Principal Investigator
Mr. L.H. Donaldson, Business Official
DOE Grant No. DE-FG02-95ER81956
Amount: $67,068

Materials related problems in Kraft recovery boilers are generally associated with corrosion, and the highest corrosion rates are usually observed in the lower furnace. Presently, there are two main classes of tubing materials used in the lower furnace: (1) plain carbon steel and (2) composite tubing consisting of an inner tube of plain carbon steel and an outer tube of Type 304L stainless steel. While the plain carbon steel tubing is relatively inexpensive, it experiences severe corrosion in the sulfidizing environment of the lower furnace. The composite tubing generally performs well; however, the initial cost of the material is high and corrosion problems have been observed around the air ports of some recovery boilers. This effort will pursue the development of a new class of alloys with corrosion resistance that is equal or superior to 304L, but with a reduced cost due to significantly less chromium and nickel in the alloy. The corrosion resistance of this alloy will result from the synergistic use of chromium and silicon. Phase I will focus on the corrosion properties of the alloy, both experimentally and theoretically. Iron-based alloys prepared in the laboratory and containing different amounts of chromium plus silicon will be tested in gas atmospheres that simulate the lower furnaces. A control sample of 304L stainless steel will also undergo corrosion testing. The results will allow the determination of the necessary chromium and silicon contents required for this new alloy to show similar performance to 304L. A thermodynamic and kinetic model for the corrosion of this alloy will also be developed. The experimental and theoretical study will lay the foundation for Phase II, where issues such as the development of high temperature mechanical properties, thermomechanical processing, and weldability will be addressed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of a new class of low cost iron-based ferritic alloys that exhibit excellent corrosion resistance in the severe environments experienced in Kraft recovery boilers will be achieved. The result of this development will be lower capital costs due to lower initial material costs, lower maintenance costs because of fewer tube replacements, and lower production costs because of prolonged operation cycles. This alloy should also have applications in other industries (e.g. petrochemical) where severe corrosion problems are experienced.

34

Refractory Coatings for Improved Papermaking--Eltron Research, Inc., 2830 Wilderness Place, #E, Boulder, CO 80301-5455; (303) 440-8008
Mr. James S. Bowers, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG03-95ER81962
Amount: $75,000

In papermaking, a 17-4 ph alloy (17% chromium, 4% nickel, 0.07% carbon, balance iron) is used as a substitute substrate for the granite roll. In this project, a modified plasma arc surfacing technology, which allows selected volatile reactants to be simultaneously introduced into the plasma arc region, will be used to introduce selected ceramic refractory coatings on this metal substrate. Phase I tasks include identification and cointroduction of reactive gases, systematic modification of plasma arc geometry, and wear and corrosion resistance verification for the coatings. The planned surfacing technology is expected to simultaneously produce conformal coatings for raised, flat, and recessed alloy surface topologies. The overall methodology for the surfacing treatment of 17-4 ph alloy should improve safety, wear resistance, and paper release properties compared to granite. Plasma welding torch technology will be readily adaptable to this application by a relatively straightforward modification to the working head hardware; both inert carrier and reactive gases will be incorporated into the orifice in the formation of the coatings.

Anticipated Results/Potential Commercial Applications as described by the awardee: The application is the convenient coating of refractory compounds onto 17-4 ph alloy to be used as a substitute for the granite roll used in papermaking. The overall plasma coating technology will have generic application in a wide variety of strategies for arresting wear corrosion and, as a consequence, will find broad application in the private sector.

35

An Energy Efficient Design for a Surface Treatment Process which Improves Wear Properties of Materials--Stirling Technologies Inc., 102 Walton Lane, Oak Ridge, TN 37830-8237; (615) 483-0142
Dr. William Stirling, Principal Investigator
Mrs. Bobbie C. Stirling, Business Official
DOE Grant No. DE-FG02-95ER82078
Amount: $55,597

An economical means for improving the surface properties of materials would be of interest to many industrial applications. Ion implantation with energetic beam has been used to improve wear resistance, hardness, and erosion and cavitation resistance. However, this process has not proven to be cost effective. In an attempt to alleviate the deficiencies of the energetic beam method, plasma source ion implantation has been proposed as a simple, reliable and low cost method of implanting complex shaped objects. However, this process has not realized its potential because of secondary electrons emitted from the implanted object. Energy efficiency is reduced and X-rays are produced when the electrons strike the chamber walls which become overheated. In addition, treatment of complex shaped objects has not been successful. Based on principles and methods for electron energy control, recently developed and tested in positive ion beam energy recovery systems and in negative ion beam extraction experiments, this project will develop a design for a plasma source ion implantation system that will virtually eliminate the problem of energetic, secondary electrons. Energy efficiency will thus be greatly increased, X-rays and wall heating eliminated, and the ability to implant complex shaped objects restored. Operating costs for a system based on this design will be evaluated for treating components of interest to the paper industry.

Anticipated Results/Potential Commercial Applications as described by the awardee: A simple, energy efficient plasma source ion implantation process will have many commercial applications. Immediate applications of this process include: production of improved materials for the pulping and bleaching process in the pulp and paper industry; production of high strength/low weight materials, such as aluminum, with improved wear properties for the auto industry; and production of hard chrome on surfaces for the plating industry.

ADVANCED DRILLING TECHNOLOGY

36

High Temperature Acoustic Sensors for Drill Monitoring--Advanced Technology Materials, Inc., 7 Commerce Drive, Danbury, CT 06810-4169; (203) 794-1100
Mr. Seungmoo Choi, Principal Investigator
Mr. Daniel P. Sharkey, Business Official
DOE Grant No. DE-FG02-95ER81913
Amount: $75,000

The latest innovation in drilling technology involves "smart drilling systems" in which a wide variety of sensors and control electronics are used to guide the drilling operation. The harsh conditions encountered in the bore hole requires protection or remote mounting of the sensors and electronics. This project will examine the use of silicon carbide (SiC) to make acoustic sensors and associated electronics that can survive under the conditions encountered in drill holes. The intrinsic properties of SiC make it an ideal candidate material for operation in these environments. The large bandgap permits device operation at temperatures exceeding 650°C. SiC is also extremely inert, and thus can be used in a wide variety of corrosive environments. Phase I will fabricate a prototype SiC acoustical sensor. In Phase II, the design of the sensor will be optimized for use in drilling operations and a small scale amplifier monolithically integrated on the same chip.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned technology development will lead to the fabrication of high temperature acoustic sensors and integrated electronics. These devices have dual scientific and commercial use in drilling, automotive, aeronautic, and nuclear reactor applications.

37

A Fully Instrumented Oil-Field Drill Bit for Use with Smart Drilling Systems--Maurer Engineering Inc., 2916 West T. C. Jester, Houston, TX 77018-7098; (713) 683-8227
Dr. William C. Maurer, Principal Investigator
Dr. William C. Maurer, Business Official
DOE Grant No. DE-FG03-95ER82019
Amount: $74,049

This project will investigate the feasibility of an instrumented drill bit for downhole measurements that will provide data on conditions ahead of the drill to a "smart" drilling system. Measurements will relate to bit condition, borehole stability, lithology, and rock heterogeneities that can affect wellpath guidance. Sensors considered for the bit will include: (1) thermocouples in polycrystalline diamond cutters to provide information on bit wear and lithology, (2) accelerometers to provide information on bit vibrations, rock cutting mechanisms, and lithology, (3) focused gamma ray sensors to determine lithology ahead of the bit, (4) bit nozzle differential pressure transducers to measure drilling fluid rheology downhole, (5) annular pressure transducers for early detection of fluid influxes and kicks, and (6) sonic hole calipers to measure rock elastic properties and in-situ stresses. In Phase I, commercial sensors will be evaluated to determine their ability to survive under the harsh downhole drilling environment. Layout drawings of the instrumental bit will be made to determine transducer locations, shock monitoring requirements, and other design factors. Candidate sensors will be laboratory tested under simulated field drilling conditions (i.e., temperature, pressure, shock loads, rotary speeds) to determine their reliability. This information, plus input from operators and bit manufacturers, will be used in the final design of the instrumented bit to be built and tested in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful development of a fully instrumented bit would have significant impact on the $10 billion oil-field drilling industry. It would allow drillers to take corrective actions before drilling under hazardous conditions, thereby avoiding blowouts, environmental pollution, and other major problems. The instrumented bit would be an integral part of smart drilling systems.

ADVANCED ENVIRONMENTAL MONITORING TECHNOLOGY

38

An Inexpensive, Electronically Tunable Chemical Sensor--Adelphi Technology, Inc., 2181 Park Boulevard, Palo Alto, CA 94306-1543; (415) 328-7337
Mr. David E. Doggett, Principal Investigator
Mr. David G. Boyers, Business Official
DOE Grant No. DE-FG03-95ER81910
Amount: $75,000

This project deals with a novel optical technique to detect the presence of and measure the concentrations of chemical species. This sensor will be an inexpensive, miniature, highly-localized, in-situ probe for both gases and liquids. It will utilize the surface plasmon resonance (SPR) effect with a novel optical geometry using inexpensive components. Unlike previously designed SPR sensors which are mechanically tunable, this novel geometry permits the sensor to be electronically tunable. The unknown chemical will be absorbed into a thin film whose optical properties are then monitored. The device will be able to sense changes in real time and to rapidly identify the gases and liquids. The new method will have no moving parts and no expensive components. The device should be compact and lightweight and should lend itself to possible integrated-optics manufacturing. In Phase I, a prototype will be constructed and feasibility demonstrated by assessing the device's sensitivity to a gas. In Phase II the sensor will be modified so that it can detect several gases.

Anticipated Results/Potential Commercial Applications as described by the awardee: This sensor will have general applications for chemical species detection in utilities, drug enforcement, food production, and chemical, pesticide, and cosmetic industries. Monitoring toxic emissions from chemical industries will benefit human health, agricultural production, ecosystems harboring endangered species, and streams and forests. Monitoring the air quality in plants and buildings will allow long-term statistics about dangerous gases.

39

Direct Detection of Biological Microorganisms Based on Electron Transfer through DNA--Clinical Micro Sensors, Inc., 428 South Sierra Bonita Avenue, Pasadena, CA 91106-3502; (818) 578-0184
Dr. Jon Faiz Kayyem, Principal Investigator
Dr. Jon Faiz Kayyem, Business Official
DOE Grant No. DE-FG03-95ER81941
Amount: $75,000

Traditional methods of monitoring biological organisms involve time consuming culture techniques followed by nonspecific biochemical identification. Electron transfer through DNA provides a novel alternative mechanism for detecting specific hybridization events. This project will develop a sensitive and selective genetic diagnostic based on this mechanism. Double stranded DNA forms a well defined double helix, while single stranded probes generally form random coils. Phase I will demonstrate the difference in electron transfer efficiencies between single stranded probes and probes which have bound target DNA, since electron transfer is sensitive to molecular structure. Electron transfer donor and acceptor probes will be synthesized and attached to opposite ends of a DNA strand. Upon binding to its target gene, these probes will undergo a spectral change characteristic of electron transfer. This change will be monitored in a number of simple conditions.

Anticipated Results/Potential Commercial Applications as described by the awardee: Electron transfer through DNA has the potential to be a sensitive, direct detection technique that does not require tedious amplification or labeling steps. Both fluorescent and amperometric target-dependent probes will have a broad commercial impact in numerous fields, including environmental monitoring of bacteria and viral pathogens, biomedical research, and clinical screening for genetic markets.

40

A Portable Supercritical Fluid Extraction System for Direct Extraction of Heavy Metals from Wastewater--Durability, Inc., 1872 Pratt Drive, Blacksburg, VA 24060-6363; (703) 231-7760
Dr. Mehdi Ashraf-Khorassani, Principal Investigator
Dr. Ahmad Razyan, Business Official
DOE Grant No. DE-FG02-95ER81954
Amount: $72,833

This project will develop a portable supercritical fluid extraction system that can directly extract heavy metals from wastewater. A distinct advantage of this system is that it can remove these contaminants directly from wastewater resident at government and industrial facilities. The extraction process is accomplished by introducing a fluorinated chelating agent (hexafluoro acetylacetonate, or bistrifluoroethylene dithiocarbamate) to the contaminated sample, thereby complexing the metal and allowing the formed neutral metal chelate to be extracted in situ with supercritical carbon dioxide (CO_2) or modified supercritical CO_2. Fluorinated ligands possess higher volatility than their neutral hydrocarbon analogs and the resulting complexes exhibit a higher solubility in supercritical CO_2. A modifier such as methanol or acetonitrile will be added to the supercritical CO_2 to increase the solvating power of supercritical CO_2. Detection of the metal chelates is accomplished using gas or liquid chromatography and atomic emission or atomic absorption spectrometry. Different pressures and temperatures are applied to optimize the extraction efficiency. This method is very cost effective, since there is no solvent to dispose of, and it is very efficient because of the physical and chemical properties of supercritical fluids.

Anticipated Results/Potential Commercial Applications as described by the awardee: The supercritical fluid extraction (SFE) market segment is expected to grow very rapidly for the next five years, and it is now poised to enter its most rapid stage of development because of the adoption of hydrocarbon based extraction. However, to grow rapidly, runs utilizing SFE must be carried out on a larger scale, while becoming less expensive and more automated. It is expected the product of this research will be used by all the automotive, aerospace, and electronic industries, as well as those dealing in wastewater. This technique allows substantial savings in both materials costs (through recycling) and the cost of sludge disposal in hazardous waste landfills.

41

A Multiple Sensor for Ecosystem Monitoring--Giner, Inc., 14 Spring Street, Waltham, MA 02154-4497; (617) 899-7270
Dr. Otto J. Prohaska, Principal Investigator
Dr. Anthony B. LaConti, Business Official
DOE Grant No. DE-FG02-95ER81976
Amount: $75,000

Ecosystem monitoring becomes increasingly important with the rising number of highly damaging local and areal catastrophes which result from human errors or from naturally disastrous events. In order to detect the onset of such catastrophes in an early stage, it is planned to develop lightweight, stable, low energy-consuming, reliable gas sensor systems for unattended measurement and control units. Electrochemical macrosensor design and manufacturing capability will be combined with the cost and precision advantages of thin-film and solid-state fabrication techniques. It is planned to demonstrate the feasibility of this concept during Phase I by designing and testing a miniaturized electrochemical carbon monoxide (CO) sensor. Slight modifications of the device design could make this sensor type applicable to home and personal safety monitoring, to industrial and public service control settings, and to strategic military concerns.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated results of this project are lightweight, reliable, robust, reproducible, low maintenance, and low energy-consuming sensor which respond to fractions of ppm levels of gases such as CO, nitrogen oxides, sulfur dioxide. The sensors can be used for simple deployment at remote measurement sites and for the unattended field monitoring of environmental changes.

42

Integrated Analysis of Lipid Biomarkers, DNA, and Pollutants in Sediment Using Supercritical Fluids--Microbial Insights, Inc., 201 Center Park Drive, Suite 1440, Knoxville, TN 37922-2105; (615) 966-7356
Dr. David E. Nivens, Principal Investigator
Mr. Andrew White, Business Official
DOE Grant No. DE-FG02-95ER82027
Amount: $74,593

Supercritical fluid extraction can use the environmentally benign solvent carbon dioxide rather than organic liquids. In some applications this has been shown to be more rapid and effective than classical liquid solvent extraction. This method can also lyse bacterial cells, allowing the subsequent aqueous extraction of DNA and RNA from the same sample. Phase I will establish the feasibility of a rapid series of extractions for the integrated analysis of organic contaminants, microbial lipid biomarkers, and nucleic acids in soils and sediments. This method will also provide the operating parameters for the design of a combination sample vial and extraction chamber that will be utilized in an automated instrument to be developed in Phase II. The integration of organic contaminant, lipid biomarker, and DNA/RNA analyses on a single sample will provide more powerful information at lower cost for assessment of pollution and responses of microbial communities in samples from diverse biotechnological applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of rapid and inexpensive analysis to detect pollutants and quantify the microbial community in a single soil or subsurface sample will greatly the enhance the accuracy and cost-effectiveness of site assessments, in-situ bioremediation monitoring, and treatability studies. There is already a significant demand for a rapid, lower cost service for the characterization of microbial communities. These methods could be incorporated into an automated analysis system in collaboration with a major instrument manufacturer.

43

A Real-Time, In-Situ Monitor of Remediation by Biological and Chemical Processes--Thermalytics, Inc., 2545 Boatman Avenue, West Sacramento, CA 95691-3817; (916) 756-4840
Dr. Anthony J. Fontana, Principal Investigator
Dr. James M. Lyons, Business Official
DOE Grant No. DE-FG03-95ER82096
Amount: $75,000

This project will provide new technology to measure soil microbial metabolic activity and/or degradative chemical activities in situ and in real time. This technology will be used to examine the kinetics of remediation processes and to monitor remediation effectiveness. The technology will be used for calorimetric analysis of heat production from soil microbe metabolic activity or other chemical reactions involved in degradation. For this, a thermal probe will constructed based on a recently designed, sensitive heat flux sensor. The probe will be constructed so that it can be inserted in the soil and used to monitor rates of heat production from microbial organisms and abiotic chemical reactions when appropriate substrates, nutrients or other chemicals are added. The rationale is that the heat production rates from biological sources are proportional to the metabolic activity of viable soil microbes. For abiotic applications, the heat rate will be proportional to the level of catalysts or chemical reactants involved in reaction at the probe site. This project focuses on use of the probe for bioremediation applications. Data will be collected to establish the essential link between laboratory evidence that microbes can degrade the contaminant and field evidence that the contaminant is disappearing.

Anticipated Results/Potential Commercial Applications as described by the awardee: Since heat fluxes universally accompany chemical or biochemical reactions, there are many potential non-remediation related applications for a robust, sensitive, real-time, in-situ monitor. Monitors will be useful, for example, in tracking fermentations, chemical processes, and mechanical heat fluxes.

HUMAN GENOME

44

Microgenetics: Techniques for Screening Large Insert Libraries--Applied Genetics Laboratories, Inc., 1335 Gateway Drive, Suite 2001, Melbourne, FL 32901-2637; (407) 768-2048
Dr. Saika Aytay, Principal Investigator
Dr. John C. Hozier, Business Official
DOE Grant No. DE-FG02-95ER81924
Amount: $75,000

This project involves a nascent micro-scale technology for producing and manipulating (including sub-cloning) recombinant DNA libraries, with a special emphasis on screening yeast artificial chromosome (YAC) libraries. The new technology is a variation of the "baby machine", a well-established culturing technique, in which a population of dividing cells is attached firmly to a surface, and the progeny cells are released into the media for collection. The difference is that the progeny cells are collected on a surface in a pattern similar to the original, thus forming a replica. Specifically, mother cells are immobilized on a flat surface, forming a library of single cells or "microcolonies". The mother cell plate is inverted over a second plate, which serves as a collecting surface for the progeny cells as they are released from the mother, forming a replica in substantially the same pattern as the mother cells (replica formation). Cells on the replica surface are fixed in situ, and sequence-specific biotinylated probes are hybridized to the chromosomes using standard fluorescence in-situ hybridization techniques. Alternatively, chromosomal target regions are amplified directly by in-situ polymerase chain reaction using a unique set of primers in the presence of biotin deoxyuridine triphosphate. Positive microclones are detected by fluorescence microscopy, and the viable positive mother cell is removed from the mother plate with a micromanipulator-driven micropipette. The mother cell is then cultured and propagated for further analysis (screening, detection, and isolation). Phase I involves developing technology for screening YAC libraries, and for detection and isolation of YAC clones. It is planned that a YAC library of 30,000 clones can be screened on a single microscope slide, providing a many-fold increase in efficiency over current technology. This technology also reduces the library from a stack of hundreds of microtiter plates to a single surface. Individualized treatment of clones only occurs after the identifying screening step.

Anticipated Results/Potential Commercial Applications as described by the awardee: YAC library screening could be provided as a service to the many research labs interested in isolating specific YACs on a "one-time" basis. YAC screening kits and charge coupled device-based hardware for signal detection could be developed and provided so the user could screen directly. This technology has applications in many areas of genome analysis.

45

A Piezoelectric Biosensor Using Peptide Nucleic Acids for Triplex Capture--BIODE, Inc.,
2 Oakwood Road, Cape Elizabeth, ME 04107-2025;
(207) 883-1492
Dr. Douglas J. McAllister, Principal Investigator
Dr. Douglas J. McAllister, Business Official
DOE Grant No. DE-FG02-95ER81933
Amount: $74,775

There are extensive commercial applications for a simple, automated detector that is capable of simultaneously processing multiple genomic samples. An instrument that could amplify a family of polymorphic gene sequences via polymerase chain reaction (PCR) and then quantitate the multiple mutations of this gene would be highly desirable. By amplifying all versions of a given gene (employing inclusive primers) and then selectively detecting the various polymorphic forms employing short, selective probes on a sensor array, it is possible to quantitate each of the mutations of the gene. One approach to such a detector employs a surface transverse wave (STW) piezoelectric biosensor using triplex capture. This would potentially allow rapid detection (within a few minutes) of minute quantities (approximately 10 pg/ml) of ds-DNA. However, even detection levels of picograms per milliliter are inadequate when "single copy number" is the technical goal. Fortunately, it is possible to reliably detect extremely low copy numbers of a specific DNA sequence using the PCR. When DNA probes are employed for triplex capture, relatively long (>16 base) probes are required, which makes it difficult to distinguish point mutations. Phase I will develop an array of piezoelectric sensors for genomic polymorphism detection. Peptide nucleic acid (PNA) probes will be employed since they have higher affinity (allowing shorter, more specific probes) and are capable of triplex capture under a wide range of solution conditions without the use of additives such as spermine.

Anticipated Results/Potential Commercial Applications as described by the awardee: By combining the sensitivity of the piezoelectric biosensor with the sensitivity of PCR, and the specificity of triple helix capture, a novel nucleic acid detection technology with the potential to overcome the drawbacks of existing technology is being created. This new DNA biosensor would operate in a continuous and, therefore, homogeneous mode and yet equal or exceed the sensitivity limits of existing dot-blot technologies. It is expected that in its final form, the biosensor will respond rapidly, in situ, with the target ds-DNA directly following, or even during, PCR amplification without the need for pretreatment or denaturation, in contrast with current technology.

COMPUTERIZED PROCESSING OF BIOLOGICAL DATA

46

A Graphical Ad Hoc Query Interface Capable of Accessing Heterogeneous Public Genome Databases--A. J. Boggs & Company, 4136 Shoals Drive, Okemos, MI 48864-3468; (313) 761-5688
Mr. J. Clarke Anderson, Principal Investigator
Mr. James D. Anderson, Business Official
DOE Grant No. DE-FG02-95ER81906
Amount: $74,992

Interoperability with public genome databases is expected to be crucial in making the Human Genome Project a success. This project will develop software tools in which users of the genome community can learn and/or examine public genome database schemes in a relatively short time and can easily produce a correctly structured query language (SQL) expression. Tools will be developed which will allow users to access both the genome database (GDB) and the genome sequence database (GSDB) simultaneously. Phase I will address one of the key problems affecting the usefulness of a distributed SQL interface; namely, a user who is not familiar with one of the two public genome databases would have difficulty understanding the schema of that database. Consequently, the user may not be able to import relevant database schemes among the many available ones and may have difficulty forming correct SQL expressions. In a federated database environment, this problem of dealing with unfamiliar third party database schemes becomes much more severe because of the added complexity. Phase I will design features that aid users in understanding GDB and GSDB schemes quickly and embed them as a part of the distributed SQL interface. The feasibility of using a Galaxy graphical user interface development tool kit to build the interface will be tested. The ultimate goal is to make the interface system portable across multiple hardware platforms, i.e., Unix workstations, personal computers, and Macintoshes. The interface will be a client program, and, by developing the client program to be portable across different platforms, the interface will be usable by the widest possible user groups.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project has a potential for revolutionizing ways in which researchers access data from public genome databases. Immediate target user groups are researchers and scientists in genome centers around the world who will have access to the Internet. The user groups can be extended to researchers in the biotechnology, pharmaceutical, and health industries. Ultimately, use of this tool is not restricted to the genome community. It can be used in other scientific communities as well as Government and corporate communities that use distributed databases.

47

GRAIL-GenQuest: A Comprehensive Computational System for DNA Sequence Analysis--ApoCom, Inc., 1020 Commerce Park Drive, Suite F, Oak Ridge, TN 37830; (615) 637-8515
Dr. Ruth Ann Manning, Principal Investigator
Dr. Ruth Ann Manning, Business Official
DOE Grant No. DE-FG02-95ER81923
Amount: $74,971

While DNA sequencing in the Genome Project is occurring fairly systematically, biotechnology companies have focused on sequencing regions thought to contain particular disease genes. The client-server DNA sequence analysis system, GRAIL, is the most accurate and widely used computer-based system for locating and characterizing genes in DNA sequences, but it is not accessible to many biotechnology environments. The GRAIL client software and graphical displays have been developed for high-end UNIX-based computer workstations. While such workstations are standard equipment in universities and large companies, personal computers (PCs) and Macintosh computers are more prevalent within the biotechnology community. This Phase I project will design Macintosh- and Windows-based GRAIL client-server prototypes for human and other model organisms with error tolerant algorithms. Because parallel processing is a viable solution for searching through the ever-increasing volume of data, Phase I will also include the parallelization of genQuest, the sequence comparison server portion of the GRAIL system. This will be accomplished by using PVM (Parallel Virtual Machine) to facilitate the development of genQuest servers on networks of PCs, workstations, and other innovative, high-performance computer architectures.

Anticipated Results/Potential Commercial Applications as described by the awardee: Prototype graphical interface systems for Macintosh, DOS Windows, and Windows that mimic the function and operation of the current GRAIL-genQuest clients will enable a larger portion of biotechnology companies to make use of the GRAIL suite of analysis tools. Parallel genQuest servers would increase the response time for searches and increase the user capacity per server. Such fast distributed computing solutions improve the cost-performance ratio and make parallel searchers more affordable to the biotechnology community.

48

Large Detector Array X-ray Absorption Spectroscopy Data Acquisition and Analysis Software--X-ray Instrumentation Associates, 2513 Charleston Road, Suite 207, Mountain View, CA 94043-1607; (415) 903-9980
Dr. William K. Warburton, Principal Investigator
Dr. William K. Warburton, Business Official
DOE Grant No. DE-FG03-95ER82102
Amount: $75,000

X-ray absorption spectroscopy (XAS) at synchrotron x-ray sources is gaining increasing importance as a technique for obtaining both structural and, increasingly, electronic information about metal atoms in molecules of biological interest. Because these system are dilute, data are collected in fluorescence mode and are almost always detector limited. This problem is being addressed by using detector arrays: 13 pixel arrays are now common, 30-100 pixel arrays are appearing, and proposals exist for 1000 pixel arrays. For these array detectors, however, traditional methods of data collection, inspection, and analysis are no longer adequate. For the XAS technique to yield accurate, consistent, and reproducible results, care must be taken at every step--from setting up the spectrometer in the beginning to adjusting model fitting parameters at the end. Unfortunately, as the number of detector pixels increases, it becomes increasingly difficult to maintain this high level of care. This issue will be addressed via a unified data collection and preprocessing software package seamlessly interfaced with advanced XAS analysis software currently being developed at the Stanford Synchrotron Radiation Laboratory (SSRL). This software will automate the spectrometer setup and calibration, data collection and integrity verification, and data preprocessing and coalescence. By passing data to an SSRL on-line analysis package, the scientific quality of the data can be monitored in approximately real time. Having the program operate from within the SSRL command interface minimizes program complexity and learning curve times. In Phase I the program structure will be designed, issues of portability and hardware support addressed, and robust data verification and preprocessing algorithms developed. In Phase II coding and debugging of the complete program will take place.

Anticipated Results/Potential Commercial Applications as described by the awardee: A successful project would facilitate the application of the XAS technique to molecular structural studies using multi-pixel array detectors at synchrotron research facilities both in the United States and worldwide. The software could either be sold directly or bundled with detector systems to increase their marketability.

ATMOSPHERIC MEASUREMENT AND SAMPLING TECHNOLOGIES

49

An Optical Water Vapor Sensor for Unmanned Aerial Vehicles--Aerodyne Research, Inc., 45 Manning Road, Billerica, MA 01821-3976; (508) 663-9500
Dr. Paul L. Kebabian, Principal Investigator
Dr. Charles E. Kolb, Business Official
DOE Grant No. DE-FG02-95ER81915
Amount: $75,000

This project addresses the need for a compact, light weight, low-power-consumption instrument, carried on unmanned aerial vehicles, to monitor water vapor concentration under stratospheric conditions. It is based on optical absorption by water vapor in the 940 nm spectral region. One of the lines in the spectrum of a gas discharge lamp is close to a strong water vapor absorption line, and Zeeman splitting with a modest magnetic field strength divides the selected spectral line into two components: an analytical line that is coincident with the water vapor absorption line, and a reference line that is negligibly absorbed. The analytical and reference lines have opposite circular polarizations, and they will be selected alternately by a polarization modulator. The light from this source will be transmitted through a multiple pass absorption cell, which provides an absorption path of (typically) 36 meters. Phase I goals include optimization of the discharge lamp design, optimization of the coupling of the light into and out of the absorption cell, and demonstration of water vapor detection performance.

Anticipated Results/Potential Commercial Applications as described by the awardee: There are many industrial applications where low water vapor concentrations must be measured and controlled. This sensor offers the advantages of sensitivity, fast response, stable and reproducible calibration, freedom from adjustment, and low cost.

50

An Automated Infrared Shadowdisk Radiometer--Yankee Environmental Systems, Inc., 101 Industrial Road, P.O. Box 746, Turners Falls, MA 01376-0746; (413) 863-0200
Mr. Mark C. Beaubien, Principal Investigator
Ms. Jane E. Herchenreder, Business Official
DOE Grant No. DE-FG02-95ER82104
Amount: $75,000

Recent concern over widespread global warming has highlighted the need for improved instrumentation for measuring atmospheric long wave (infrared) radiation. Currently available infrared field instruments (e.g., pyrgeometers) are fraught with technical problems and have not been updated in the past 25 years. This project will make and test an innovative, low cost, high precision, prototype instrument for scientific, atmospheric radiation field experiments studying long wave radiation. The automated infrared shadowdisk (AIRS) radiometer is based upon an innovative electro-optic design. While several components of AIRS will be borrowed from existing field-proven instruments, this effort is not just an extension of existing instrumentation. Phase I experiments are designed to intensively investigate several detection technologies via prototypes in an attempt to gain a better understanding of the limits of ultra-high precision laboratory detectors when deployed in the field. Based on the result of these, a preliminary instrument design will be developed along with a computer-driven shadowdisk.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of instrumentation having the described performance will create a new world of possibilities for the atmospheric sciences. Precision infrared instruments are used in long term climate experiments, often deployed on a wide-scale over the globe. With the renewed concern over global climate change, experiments are being designed that require more accurate instruments. There are also many industrial applications where precise infrared radiometry can reduce the manufacturing cost of materials.

51

Development of a Low Cost, Narrowband, Solar Ultraviolet Spectroradiometer for Field Use--
Yankee Environmental Systems, Inc., 101 Industrial Road, P.O. Box 746, Turners Falls, MA 01376-0746; (413) 863-0200
Mr. Mark C. Beaubien, Principal Investigator
Ms. Jane E. Herchenreder, Business Official
DOE Grant No. DE-FG02-95ER82103
Amount: $75,000

The depletion of the ozone layer and its effects on ultraviolet (UV) irradiance levels at the surface of the Earth has highlighted the need for improved instrumentation for measuring solar UV radiation. This project will lead to the development of low cost UV instrumentation with narrow band spectral sensitivities in the UV regions of current scientific interest. The detectors are based on a novel, dual prism-dispersion photometer with few moving parts and a cadmium tellurium photomultiplier detector. The instrument employs a computer-controlled shadowband for making direct, diffuse, and total irradiance measurements. Phase I will develop and test a laboratory prototype of the detection scheme. The new instrument is based upon several key technology components borrowed from existing widely-used field instruments.

Anticipated Results/Potential Commercial Applications as described by the awardee: The commercial application of this research is the development of new, low-cost, narrowband, solar ultraviolet irradiance, commercial instrumentation. The planned instrument would find a ready market in several large scale scientific networks as well as other international scientific research programs.

MEDICAL APPLICATIONS

52

An Advanced Scintillator for Medical Imaging--
Mission Support, Inc., P.O. Box 511283, Salt Lake City, UT 84151-1283; (801) 773-7900
Dr. J. Bart Czirr, Principal Investigator
Mr. David B. Merrill, Business Official
DOE Grant No. DE-FG03-95ER82033
Amount: $74,765

This project will adapt and improve a new scintillating material, cerium-activated lanthanum beryllate, for applications in medical imaging. This material was developed as a scintillator for nuclear particle detection in the field of oil well logging. The present gamma ray energy resolution is inadequate for medical imaging purposes and the primary goal of Phase I is to increase the light output by a factor of three. The light output will be improved by increasing the cerium content from the current concentration of 0.09% to one to two percent. If this goal is achieved, the new material could provide superior energy resolution over bismuth germanate and thallium doped sodium iodide in positron emission tomography (PET) and single photon emission computed tomography applications. Initial estimates indicate that a successful project would increase the energy resolution relative to bismuth germanate PET systems by greater than 20%.

Anticipated Results/Potential Commercial Applications as described by the awardee: An improved scintillator based upon cerium-activated lanthanum beryllate will result in improved energy and spatial resolution for the detection of gamma rays in medical imaging applications.

HIGH ENERGY PHYSICS EDUCATIONAL AND TEACHING AIDS

53

Interactive Multimedia Software for Fundamental Particles and Forces--Context Productions, 1495 Masonic Avenue, San Francisco, CA 94117-4525; (415) 252-1492
Mr. Jack Sculley, Principal Investigator
Ms. Terry Brooks, Business Official
DOE Grant No. DE-FG03-95ER81944
Amount: $74,460

An interactive multimedia program will be developed that can be used by students and other individuals to learn about fundamental particles and forces. It will illustrate the experimental techniques used in high energy physics research and allow students to gain access to representative experimental data from National Laboratories over electronic networks. The project will combine expertise in interactive multimedia educational software with that in science and education to develop a state-of-the-art compact disk-read only memory product. The product will integrate advanced multimedia technologies (such as digital video, three dimensional animations, and stereo sounds), with experimental simulations and narrative design techniques to provide a truly interactive, engaging, and enriching learning experience. Phase I will evaluate the use of existing software in classroom situations, solicit feedback from students and the general public at the Exploratorium in San Francisco, create innovative techniques for communicating the core concepts of high energy physics, and locate available audiovisual resources from the private sector and Government facilities. This information will be incorporated into the design of the interactive multimedia program to include storyboards, an audiovisual script, and an interactivity flowchart. The Phase I research will provide a sound framework for intensive production of the software in Phase II. The primary goal of Phase II is to develop meaningful interactive learning experiences with high energy physics concepts.

Anticipated Results/Potential Commercial Applications as described by the awardee: The resulting product will be a technologically innovative educational program compatible with most widely available machines in schools and homes. Publishing plans include marketing and distribution through top educational software distributors, retail channels, "super-stores", museum stores, original equipment manufacturer bundling and possible derivative products on on-line services.

54

An Apparatus for Demonstrations and Hands-On Experiments in the Science and Technology of Charged Particles in Vacuum--Harrison Scientific Corporation, Mt. Agassiz, P.O. Box 660, Bethlehem, NH 03574-0660; (617) 357-9740
Mr. Stanley Harrison, Principal Investigator
Mr. Jeffrey M. Feldman, Business Official
DOE Grant No. DE-FG02-95ER81981
Amount: $72,691

Areas of physics experimentation requiring high vacuum, including the whole field of particle physics, have been relatively unavailable for undergraduates. Yet, vacuum is used in most scientific or technological fields including physics, optics, materials science, and semiconductors. The complexity and unreliability of older vacuum system designs has precluded student use. This project will design a vacuum system which is appropriate for use by neophyte students. Once high vacuum is available in the classroom, a wide variety of physics and technology demonstrations and experiments becomes newly available to teacher and student. Through a hands-on approach and strong visual feedback, the apparatus will make charged particle phenomena come alive for students. Experiments will be designed which can be assembled into both preconceived instructional and student-conceived experimental setups. These experiments will include electron beams, ion beams, particle accelerators, and mass spectrometers. In Phase I, a prototype of a simple and reliable overall vacuum apparatus will be made. Vacuum components, which can be assembled into a limited number of different particle beam experiments (e.g., cathode ray tube, vacuum gauge, charge to mass ratio), will be designed, fabricated, and tested. An effort will also be made to explore and evaluate the feasibility of many further experiments made possible by this kind of apparatus, with an eye to the potential for development during Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will produce a stimulating scientific experience to attract and teach young scientists. This equipment and associated teaching materials should be used in high school, technical preparatory school, and college physics laboratories, as well as in continuing education and/or technical training for technicians in research and development laboratories and industry, for both demonstration and hands-on experience with vacuum and a wide range of particle beam technologies.

55

An Interactive System for Educational Instruction in High Energy Physics--Invocon, Inc., 9001 Interstate 45 South, Suite 530, Conroe, TX 77385-8703; (713) 292-9903
Mr. Karl Kiefer, Principal Investigator
Mr. Karl Kiefer, Business Official
DOE Grant No. DE-FG03-95ER82005
Amount: $74,987

A need exists to develop educational aids in the field of high energy physics (HEP). Current hardware systems are expensive and at times hazardous. The process of learning can be enhanced by specific visualization capabilities that can quickly orient the beginning student and capture his interest with the perception of reality. This project deals with the potential educational benefits of multimedia visualization and the creation of images that cannot be observed under normal conditions. Phase I will result in the design of an interactive experimentation system that is directly aimed at educational instruction in high energy physics. HEP hardware will be built that can safely, reliably, and inexpensively serve as a teaching aid and still demonstrate practical applications. There will also be a sophisticated interactive visualization capability that will allow the student to "see" high energy particle performance as various experiments are carried out. This package will take actual data from the HEP hardware and visually and aurally depict the process that cannot be seen with the naked eye. The system will be designed for a market with clearly defined sales forecasts so that ultimate volume can be accurately estimated. The market analysis will show what the user can pay for the product. It will also identify the current players in the market that represent competition or a good potential commercialization partner with an established marketing and customer service network.

Anticipated Results/Potential Commercial Applications as described by the awardee: The project will produce a commercially viable HEP instructional system focused on high school through undergraduate level university physics. The Phase I effort will demonstrate that safe hardware can be built at a cost that will be palatable to the end users. Commercial markets include all high schools, junior colleges, and undergraduate universities.

56

Interactive Particle Detector Teaching Aids Based on Plastic Scintillators--Quantum Research Services, Inc., 5410 Apex Highway, Suite W, Durham, NC 27713-9434; (919) 544-4952
Dr. William L. Dunn, Principal Investigator
Dr. William L. Dunn, Business Official
DOE Grant No. DE-FG02-95ER82057
Amount: $75,000

A suite of plastic scintillator detector devices is planned from which physics resource kits can be assembled to help high school and undergraduate college students learn about radiation, its detection, and some of its many uses. The resource kits will contain fibers, fiber ribbons, and bulk scintillator that are used to demonstrate particle detection and tracking. Excitation by various forms of nonionizing and ionizing radiation will be demonstrated. Students will be able to conduct participatory experiments with the resource kits through personal computers, gaining an understanding and appreciation of high energy physics techniques and exploring radiation applications such as imaging and dosimetry. Phase I will concentrate on developing five scintillating fiber and fiber ribbon devices that respond to collimated ultraviolet and x-ray sources, constructing eight-channel hardware and software personal-computer interfaces, and conducting independent evaluation of the technology by high school and college teachers and students. The resource kit will be expanded and integrated in Phase II into a suite of interactive tools from which inexpensive teaching aids can be tailored.

Anticipated Results/Potential Commercial Applications as described by the awardee: Particle detector resource kit teaching aids based on fiber optics will provide inexpensive and exciting ways to demonstrate particle detection and applications. Widespread distribution of the resource tools can be achieved by tailoring participatory teaching aids that match the needs and resources of different high schools and colleges.

TECHNOLOGY AND INSTRUMENTATION FOR HIGH ENERGY

57

Breaking the Oscillation Barrier in High Power Microwave Tubes--Duly Research, Inc., 1912 MacArthur Street, Rancho Palos Verdes, CA 90732; (310) 548-7123
Dr. David U.L. Yu, Principal Investigator
Mrs. Carolyn Yu, Business Official
DOE Grant No. DE-FG03-95ER81953
Amount: $75,000

In order to generate very high radiofrequency (rf) power at the output of microwave tubes such as the klystron, it is necessary to operate at high electron beam current and high voltage. However, the amount of electron current transportable through a drift tube is limited by rf oscillations between cavities. This project will explore methods to suppress rf oscillation between cavities in a large-bore drift tube which propagates the dominant transverse electric mode, while cutting off the fundamental transverse magnetic mode. An enlarged drift tube can accommodate a higher current in a hollow beam while maintaining a moderate voltage and a low plasma frequency. The methods to be used include stability criteria based on cancellation of phase shift in the electron beam and the phase shift in the feedback loop between cavities, loading the drift tube and cavities with special lossy materials, and use of choke joints as severs. In Phase I, theoretical studies, numerical simulation, and component testing will be performed, and a Phase II demonstration to verify the validity of these methods will be designed. Phase II will build and test a large-bore klystron, using the gun and collector of a Stanford Linear Accelerator Laboratory 5045 klystron, and a new drift section with a 1.25 inch bore diameter and 6.84 GHz resonant cavities.

Anticipated Results/Potential Commercial Applications as described by the awardee: The revolutionary design of a large-bore, oscillation-free klystron will pave the way for cost-effective manufacturing of very high power microwave (HPM) tubes. The methods developed in this project will be applicable to a large class of HPM tubes such as conventional klystrons, extended-beam klystrons and gyro-klystrons. These tubes can be used in future linear colliders, defense applications, wireless communications, and compact, commercial linear accelerators.

58

A Thermally Stable Iron Core Permanent Magnet Dipole Utilizing a Flux Shunt--Field Effects, Inc., 6 Eastern Road, Acton, MA 01720-5801; (518) 782-1122
Mr. Robert R. Lown, Principal Investigator
Mr. Carl H. Rosner, Business Official
DOE Grant No. DE-FG02-95ER82001
Amount: $74,972

Permanent magnets (PMs) have been used for some time in charged particle accelerators. Historically, their temperature stability has been achieved by either the selection of a PM material which has an inherently small magnetic variation with temperature or by active control of the thermal environment These approaches have the disadvantages of high cost and increased complexity, respectively. An alternative is to use inexpensive ceramic ferrite PM material coupled with a passive flux shunt to compensate for the relatively high temperature sensitivity of that material. Potential applications include large fixed strength storage rings. For these, a method to passively compensate for the effects of temperature on the field strength of the PM material will enable inexpensive, simple, and reliable magnets to replace the more expensive resistive magnets used now. This project will develop and demonstrate a passive method for reducing the effects of temperature on the field strength of a permanent magnet iron core dipole, as would be used in a storage ring. This will be done by using a flux shunt made from a material with a saturation induction that varies with temperature. Phase I will concentrate on optimizing the design of such a magnet to minimize the effect of temperature and overall cost. A one meter long model will be fabricated to demonstrate feasibility. This will lead to a full scale prototype in Phase II and/or adaptation of the method to PM quadrupole and sextupole magnets.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that this method will lead to magnet designs that are substantially more cost effective than resistive magnets, with field temperature stability suited for use in particle storage rings. The use of PMs in this application will also result in an overall gain in system reliability. The elimination of power supplies, cooling requirements, interlocks, and controls not only reduces overall system costs, but makes the system immune to short interruptions in power. Specifically, the technology developed here is directly applicable to the proposed luminosity upgrade at the Fermi National Accelerator Laboratory, as well as light sources, stretcher rings, beamlines, and other accelerator structures.

59

An Induction Modulator for a Relativistic-Klystron Two-Beam Accelerator--FM Technologies, Inc., 10529-B Braddock Road, Patriot Square, Fairfax, VA 22032-2236; (703) 425-5111
Dr. Terry F. Godlove, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG02-95ER81972
Amount: $74,930

This project is concerned with a new concept for a relativistic-klystron, two-beam accelerator (RK-TBA). Power from a low energy, high current, bunched beam is converted to microwaves via the klystron mechanism and used to drive a high energy linac, specifically a future 1-TeV (center-of-mass) Next Linear Collider (NLC). The project will concentrate on a critical subsystem: an induction core assembly and modulator for the low energy accelerator. Some thousands of these units would be required for a full-scale collider. Phase I will complete preliminary design including tradeoffs in key parameters and will take full advantage of the most recent developments in high-power magnetic materials, switches, and nonlinear pulse-forming techniques. Phase II will consist of the design, development, fabrication and test of a prototype induction core assembly, including the required high-power modulator. A detailed characterization and assessment will be completed.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful development of modulators and cores for a two-beam accelerator will enable DOE to assess this potentially promising method in a far more definitive manner than is available from conceptual studies. This is particularly true of cost and key parameters such as electrical efficiency. In addition, development of such modules will give major impetus to other applications, including more powerful electron linacs for industry and medicine, and high-power ion linacs for pulsed spallation neutron sources and materials irradiation.

60

Suppression of Voltage Breakdown in High-Gradient Radiofrequency Cavities--FM Technologies, Inc., 10529-B Braddock Road, Patriot Square, Fairfax, VA 22032-2236; (703) 425-5111
Dr. William K. Peter, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG02-95ER81973
Amount: $74,955

This project will demonstrate a promising concept for raising the breakdown limit in radiofrequency (rf) cavities by the use of semiconducting or insulating cavity coatings. The primary purpose of the thin coatings (<<1 micron) described here is to reduce the field emission while keeping the secondary emission low. The surface coating acts to isolate electrode whiskers from the cavity chamber and to serve as a trap for slow electrons and low-mass ions. One previous experiment based on this model has been carried out and has demonstrated suppression of field emission by up to six orders of magnitude and increased the standoff voltage by approximately 50%. In Phase I, feasibility will be established by repeating and extending this experiment with additional coatings and tests. This promising concept was not tried on rf cavities and has not yet enjoyed further demonstration. It is planned to design a series of high-power rf cavity tests at the Stanford Linear Accelerator (SLAC) in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: A new type of cavity coating is designed to suppress cavity breakdown in high gradient rf accelerating structures (gradient >100 MeV/m for electrons and >10 MeV/m for protons). If successful, this coating could prevent high-voltage breakdown in a large number of accelerating structures.

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Design of a Radiofrequency-Extraction Structure for a Relativistic Klystron Two-Beam-Accelerator--Fusion and Accelerator Research, 3146 Bunche Avenue, San Diego, CA 92122-2247; (619) 455-6607
Dr. Jin-Soo Kim, Principal Investigator
Dr. Jin-Soo Kim, Business Official
DOE Grant No. DE-FG03-95ER81974
Amount: $74,997

There is currently considerable effort in the United States and abroad on high energy electron-positron linear colliders. It is important that a linear collider can be extended to significantly high energy to put it on the frontier for high energy physics. In Phase I, the design of several radiofrequency (rf) - extraction structures that could be used in the rf power source of a future one teraelectron-volt (TeV) linear collider based on the relativistic-klystron two-beam accelerator concept will be evaluated. The structures will be designed to produce 360 megawatts of rf power at 11.4 gigahertz every two meters of the high-gradient accelerator of the linear collider. The design of the structures must yield a system that has a low beam break-up growth rate for the drive beam, maintains the longitudinal bunching of the drive beam as it passes through multiple structures, has modest electric field surface stresses, and can be produced at low cost. The design of a dielectric-loaded rf structure, the use of Bragg reflectors, as well as various geometries of disk-loaded traveling wave structures will be explored. First, the best candidates will be selected based on single mode analysis and two dimensional computer codes. The results from these codes will produce a more accurate structure design which must be evaluated for the above stated performance measures. From the optimum designs a few structure prototypes will be manufactured and tested in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee. The Phase I effort will lead to the design of rf-extraction structures that could be used in the rf power source of a future one-TeV linear collider based on the relativistic-klystron two-beam accelerator concept. The rf structures that will be produced in Phase II can be tested in a prototype machine which is being built. This work could also advance compact high energy electron accelerators for use in efficient lithography, and in materials processing systems.

62

An Intelligent Graphics Interface for Particle Optics and Accelerator Design--G. H. Gillespie Associates, Inc., P.O. Box 2961, Del Mar, CA 92014-5961; (619) 677-0076
Dr. George H. Gillespie, Principal Investigator
Dr. George H. Gillespie, Business Official
DOE Grant No. DE-FG03-95ER81975
Amount: $74,995

The intelligent graphics interface for particle optics and accelerator design represents a new approach to software tools for analyzing high energy physics accelerators. A sophisticated graphical user interface (GUI), incorporating expert system features, will be combined with state-of-the-art charged particle optics and accelerator simulation codes. A modular structure allows the GUI and the simulation codes to be customized to each class of accelerator or optics problem. Existing Fortran codes, as well as codes in other languages, can be compiled and linked with the intelligent graphics interface. Particle optics, beamlines, and complete accelerator systems are built using drag and drop icons in a window system developed specially for particle optics modeling. The same beamline problems may be run using top-level scaling models, Lie algebra programs, matrix and envelope codes, or multiparticle simulations. Beamlines are moved from one computation model to another simply by copying and pasting the icons from one window to another. A novel data translation algorithm automatically converts the beamline representation to the required format. In Phase I, a demonstration prototype of the GUI, integrated with several codes used in the design of high energy accelerators, will be completed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The intelligent graphics interface for particle optics and accelerator design will prove a new software tool that improves scientific productivity in solving problems associated with design of particle accelerators and beamlines. The tool will equip scientists and engineers with new capabilities for efficiently modeling and analyzing charged particle beamlines and accelerator systems.

63

A Relativistic Klystron High Power Ceramic Window and Output Structure to Maximize Conversion Efficiency--Haimson Research Corporation, 3350 Scott Boulevard, Building 60, Santa Clara, CA 95054-3122; (408) 988-6007
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-95ER81980
Amount: $74,422

In this project, a flexible test vehicle will be designed that will enable critical relativistic klystron parameters to be conveniently altered and optimized. The objective is to explore the maximum efficiency that can be achieved with a relativistic klystron operating at 17 gigahertz (GHz) with an optimally designed high power traveling wave (TW) output structure and a 60 MW, 0.25 microperveance electron beam. Although theoretical maximum conversion efficiencies of 65 to 70% have been quoted for low perveance, high power relativistic klystrons, maximum efficiencies actually demonstrated have been limited to approximately 50%. Phase I will involve the design of an experimental tube configuration that will: (1) allow the major limiting factors of conversion efficiency to be quantitatively identified for low beam perveance TW relativistic klystrons, (2) establish a maximum efficiency, near optimum parameter combination, and (3) provide a valuable resource for evaluating the accuracy of computer-predicted results. Since no microwave windows are presently available that can operate at the power levels anticipated with an efficiency-optimized 17 GHz relativistic klystron amplifier, a further objective is the design of high power ceramic window assemblies. In Phase II, the experimentally flexible tube configuration and the high power output window assemblies shall be fabricated and tested at high power. This will allow the klystron circuit parameters to be optimized in order to realize the maximum practical conversion efficiency.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated, if successful, that the Phase I and Phase II efforts will result in a ceramic window sealed, optimum efficiency, TW relativistic klystron suitable for linear collider research and high peak power commercial radio frequency applications.

64

Development of Low-Cost Cryogenic Amplifiers for High-Resolution Particle Detectors in High Energy Physics Research--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523-1101; (914) 592-1190
Dr. Masoud Radparvar, Principal Investigator
Dr. Elie K. Track, Business Official
DOE Grant No. DE FG02-95ER81989
Amount: $74,872

Cryogenic particle detectors provide the best energy resolution, particle identification, and spatial imaging in high energy physics research. These detectors have been instrumented with high-impedance field effect transistor (FET) amplifiers. However, these amplifiers require heated operation (silicon (Si) junction FETs >150 K) or suffer from large noise (gallium arsenide metal oxide semiconductor FETs at 1 K), are very sensitive to microphonic pickup, and dissipate high power (> 1 mW per channel). Superconducting quantum interference device (SQUID) amplifiers solve all these problems. However, commercial SQUID systems are expensive (approximately $10,000 per channel) and have limited bandwidths (<50 kHz). A novel approach for implementing a wide bandwidth and inexpensive SQUID readout scheme was recently proposed. This project will develop a complete SQUID amplifier system, with associated room temperature electronics, which exhibits a sensitivity better than 1 pA/√Hz and has low cost (less than $2,000 per channel). In addition, the array heat dissipation is approximately 1 μW per channel, and the usable bandwidth is > 1 MHz. The goal is to develop a commercial low-cost SQUID amplifier system for multi-channel cryogenic particle detector applications. During Phase I, a four-channel prototype system will be built and tested. Its utility for the readout of a one gram position-sensitive Si detector, capable of nuclear recoil versus electron recoil discrimination, will be demonstrated. During Phase II, the commercial design for multi-channel applications would be completed, and a 40-channel system for a 500 g Si dark matter experiment demonstrated.

Anticipated Results/Potential Commercial Applications as described by the awardee: The availability of such low-cost SQUID amplifiers would result in their use for nearly all high energy physics research experiments, high resolution x-ray spectroscopy, imaging detectors, and particle identification systems. The first of these applications has a potentially large commercial market for electron diffusion spectroscopy in electron microscope systems for material surface characterization studies. The SQUID magnetometer system also has applications in medical fields as a biomagnetometer for mapping of brain functions to identify the location of somatosensory, motor, auditory, etc. regions of the brain. In addition, this system can also be used in detection of corrosion and cracks in aircraft.

65

Enhanced Flux Pinning at High Fields in Niobium-Titanium-Tantalum by Magnetic Artificial Pinning Centers--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06704-1039; (203) 753-5215
Dr. Leszek R. Motowidlo, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-95ER81991
Amount: $75,000

The significance of engineered artificial pinning centers (APCs) in niobium-titanium-tantalum (NbTiTa) superconductors has been recognized world wide, and today it is one of the most important areas of materials research in applied superconductivity. This approach has yielded record high critical current (J_c) below 4 T and, at some fields, is almost a factor of two better, surpassing that of the conventionally optimized NbTi wires. Enhanced fluxon pinning is possible because of the much greater freedom which is available in the design of the pinning arrays in APCs. The benefits of this approach from the standpoint of flux pinning are threefold. By manipulating the starting materials and geometries, optimization can be sought for: (1) the number of pinning sites, (2) the size and geometry of pinning sites, and (3) the strength of the individual wells. The main objective of Phase I will be to demonstrate the technical feasibility of significant J_c improvement at high fields ($B > 8$ T) in NbTiTa through the incorporation of magnetic APCs in the correct volume percent using a novel design. The successful technical completion of the project will result in significant cost reduction in conductors for high energy accelerators as well as for the commercial magnetic resonance imaging (MRI) industry.

Anticipated Results/Potential Commercial Applications as described by the awardee: The primary result of this research is the development of a cost-effective APC NbTiTa superconductor with a critical current density far superior to any that is commercially available today. It is expected that the J_c will be attractive over a wide range of magnetic fields. Applications that will benefit include magnets for future high energy physics accelerators, whole body MRI scanners, magnetically levitated transportation, and superconducting magnetic energy storage.

66

An Efficient, Cost-Effective Power Modulator for Advanced Klystrons--Integrated Applied Physics, Inc., 2701 Plaza Del Amo, Suite 702, Torrance, CA 90503-7314; (310) 533-5182
Dr. Isif Yampolsky, Principal Investigator
Mr. Nathan Burleson Jr., Business Official
DOE Grant No. DE-FG03-95ER81999
Amount: $74,994

The development of efficient power modulators with high voltage, high power, and fast rising pulses is a very important step towards the next generation of linear accelerators. Such modulators are also needed for commercial applications, such as waste treatment, where there are limitations in reliability and implementation. This project will develop a power modulator producing 400 kV peak output voltage, 100 A peak output current, 250 nsec pulse length, at repetition rates up to several hundred Hz. The power modulator will be used to directly drive radiofrequency (rf) power sources for the next linear collider, including cluster klystron devices. The approach promises cost effectiveness and high efficiency (80%), with considerable reduction in size compared to direct current (DC) sources. If the DC sources are replaced by the power modulator, the protection circuits in the system can also be eliminated. The planned power modulator minimizes the voltage requirement on the switches and eliminates the output transformer. This will allow fast rise time 250 nsec pulses. Future versions can be straightforwardly implemented at the one MV level. The modulator is based on innovations in modulator design and will produce an output 10 times the input switch voltage while preserving fast rise time. Phase I will demonstrate a 150 kV output with 40 nsec rise time.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result will be an rf power modulator suitable for present klystron evaluations and capable of being increased in power as klystron development proceeds. The novel voltage multiplication modulator concept greatly reduces the stress on the switching components allowing low cost reliable switches to be applied. The overall result will be a reduction in cost while increasing the reliability and efficiency of the rf power systems for high power applications. Commercial applications include industrial electron accelerators for water treatment, for sterilization, and for pollution control.

67

Development of a 10 Megawatt L-Band Klystron Amplifier--MDS Company, 1955 Mountain Boulevard, Suite 101, Oakland, CA 94611-2812; (510) 339-0957
Dr. Patrick Ferguson, Principal Investigator
Dr. Patrick Ferguson, Business Official
DOE Grant No. DE-FG03-95ER82020
Amount: $75,000

By means of analysis, computer simulation, and radiofrequency (RF) testing, this project will design a 10 MW klystron operating at 1.3 GHz with 10 Hz pulse repetition rate and a minimum pulse width of 2.0 milliseconds. The analysis, design and simulation will be based on conventional klystron theory. In Phase I an electron gun capable of generating a 210 kV - 72A solid electron beam from a thermionic cathode operating in ultra-high vacuum will be designed. An electromagnetic-electron beam interaction circuit capable of producing 10 MW with a minimum saturated gain of 50 dB and a minimum efficiency of 65% will be designed by computer simulation. A multiple cavity extended interaction output circuit capable of efficiently extracting the fundamental RF power from the electron beam will be designed and analyzed for possible RF electric field breakdown. High thermal capability, long life and robust construction will be emphasized. All cavities, including the multi-cavity extended interaction circuit and a vacuum ceramic window, will be designed, fabricated and RF tested. In Phase II, the mechanical design, fabrication, and RF testing of the various subassemblies will be completed.

Anticipated Results/Potential Commercial Applications as described by the awardee: Anticipated results are the successful design of a 10 MW high efficiency high duty klystron. This klystron could be a high power source for future linear colliders and for high gradient electron accelerators for commercial application. With additional gain cavities, this klystron can be broadbanded for military applications.

68

Efficient Thyratron/Transformer Modulators for Radiofrequency Accelerators--North Star Research Corporation, 9931 Lomas Northeast, Suite A, Albuquerque, NM 87112-5278; (505) 296-3596
Mr. Richard Adler, Principal Investigator
Mr. Richard Adler, Business Official
DOE Grant No. DE-FG03-95ER82040
Amount: $74,921

Advanced radiofrequency (rf) accelerators require state of the art power systems which are both inexpensive and efficient. Such systems can be produced by high power klystrons which in turn require inexpensive, efficient, modulators. This project will extend the applicability of high power modulator technology to 500 kV while reducing the causes of inefficiency. Such causes include the transformer capacitance, lost energy from leakage currents, and the long rise and fall times of the transformer/pulse forming network system. A high gradient transformer will be used to reduce leakage without increasing capacitance. Further reductions in capacitance will be tested by investigating the use of gas insulated transformers. Energy recovery from the main transformer inductance will be investigated. The effort will focus on a trade-off study followed by the fabrication of a full 500 kV system in Phase I.

Anticipated Results/Potential Commercial Applications as described by the awardee: If successful, this research will lead to more efficient, fast pulsed modulators for application to ion implantation, radar systems, and accelerators for semiconductor processing.

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A High Power Harmonic Magnicon--Omega-P, Inc., 202008 Yale Station, New Haven, CT 06520; (203) 458-1144
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG02-95ER82045
Amount: $75,000

In Phase I, design studies will be conducted for improvements in an 11.4 GHz frequency doubling magnicon. The magnicon, a novel scanning-beam device shown capable of amplifying microwaves to 100's of megawatt power levels, is a candidate for powering future electron-positron colliders. Calculations have shown that such a device could, in principle, have an efficiency of over 50%. To date, experimental realization of high power and high efficiency X-band magnicons has eluded researchers because of several deficiencies. These include insufficient electron beam quality, improper beam geometry, and multipactoring and/or arcing in the penultimate and output cavities. The improvements to be addressed in Phase I include design of a high convergence, high power electron gun to create a low emittance, high current density ~500 kV, 200 A beam; and modifications in the designs of the beam deflection cavities and output cavity. The Phase I design study is to form the basis for construction and testing of the gun and cavities in Phase II, and for their installation on an improved experimental magnicon.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful design improvements in Phase I will allow critical tests in Phase II of the potential for high efficiency in a ~100 MW X-band magnicon. Confirmation of the predicted high efficiency would provide an RF source as an alternative to the klystron for powering a future linear collider. Other potential uses include power beaming and deep prospecting.

70

A Microwave Inverse Cerenkov Accelerator--Omega-P, Inc., 202008 Yale Station, New Haven, CT 06520; (203) 458-1144
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG02-95ER82047
Amount: $75,000

A design is to be developed in Phase I for a prototype Microwave Inverse Cerenkov Accelerator (MICA) that will be built and evaluated in Phase II. The MICA prototype includes a waveguide in which a ~6 MeV, ~5 psec injected bunch encounters an acceleration gradient of about 10 MeV/m, emerging with a normalized transverse emittance not greater than 5π mm-mrad. Optimized design will be sought for a dielectrically-loaded accelerating waveguide liner without breakdown or multipactoring. A beam line design will be developed to allow energy filtering of the beam from an RF gun, with concomitant pulse clipping. A beam chopper will be designed to select a few bunches in sequence from the RF gun and reduce average beam loading of the accelerator, thus allowing the number of accelerated particles per bunch to approach 10^9.

Anticipated Results/Potential Commercial Applications as described by the awardee: Success in demonstrating a prototype MICA could open up commercial markets for a simple, low cost electron accelerator for small industrial and university laboratories. Applications could be in coherent radiation sources (free electron lasers, synchrotron sources) for materials R&D; and in short-pulse x-ray, neutron and alpha particle sources for materials processing, oil exploration, medical diagnostics and therapy.

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A Vacuum Beat Wave Accelerator--Omega-P, Inc., 202008 Yale Station, New Haven, CT 06520; (203) 458-1144
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG02-95ER82046
Amount: $75,000

This project will evaluate the potential for a Vacuum Beat Wave Accelerator (VBWA), in which two focused laser beams of differing wavelengths overlap in space to produce a ponderomotive beat wave that can accelerate electrons. This laser-based electron accelerator scheme differs from earlier approaches in that no plasma gas or other proximate material medium is required to support a slow wave that accelerates the particles. A periodic magnetic field, as in the inverse free electron accelerator, is also not required. For experimental parameters of existing lasers, preliminary theory indicates that an acceleration of over 100 MeV could be obtained in a single pass through an approximately 400 µm waist region where two beams, of approximately seven TW and with wavelengths 1.0 µm and 0.5 µm, overlap. Simulation studies in Phase I will determine the trapping fraction for approximately six MeV injected electrons from a laser-driven photocathode radiofrequency gun, and the growth of longitudinal and transverse emittances on the beam. Plans for design, construction, and testing of a prototype VBWA in Phase II will also be developed in Phase I.

Anticipated Results/Potential Commercial Applications as described by the awardee: A new electron acceleration scheme, capable of acceleration gradients of hundreds of GeV/m, will be developed. Uses for a beam with optical-scale bunches are in harmonic radiation sources.

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A Microwave Structure for Charged Particle Multiple Beam Devices--Schonberg Research Corporation, 3300 Keller Street, Building 101, Santa Clara, CA 95054-2612; (408) 980-9729
Dr. Andrey V. Mishin, Principal Investigator
Mr. Russell G. Schonberg, Business Official
DOE Grant No. DE-FG03-95ER82065
Amount: $74,949

The main goal of this project is to improve standard accelerator structure properties and use some advanced concepts to create a system which is capable of either enhancing the loading characteristics of linear accelerators or increasing the possible energy gain on a limited length of the structure. In some cases, the advantages of circular and linear accelerators might be combined. Particle accelerators for various applications are usually limited in length and size because of portability requirements. The intention is to shift an operating frequency to the higher values so that one could significantly reduce the outline dimensions and weight of the final package. However, in the higher frequency band one faces a problem of current restrictions among a number of other complications. Phase I will design and study a prototype of a standing wave accelerator structure which will allow the acceleration of multiple or quasi-hollow beams and improve beam loading properties, or will provide a multiple pass type operation and increase available energy gain. The expected frequency range in which the structure is most efficient should be 3 GHz and higher. A study performed for a working prototype will allow refinement of the tuning procedure and study of the microwave properties of the structure. If the study is successful, it will allow production of a working linac section and future beam testing using the existing equipment, microwave generator, and modulator during Phase II. The beam current limit, which is determined by the accelerator section aperture size, will be increased approximately by a factor of 10 depending on the mechanical interpretation The value will be limited only by beam-breakup effects caused by higher transverse mode generation and other instabilities. Energy gain is expected to be increased by a factor of $N^{1/2}$ on the fixed length in the multiple-pass type system, where N is the number of passes.

Anticipated Results/Potential Commercial Applications as described by the awardee: The potential commercial applications of the portable accelerators with the improved energy and current characteristics are, actually, in all the well known areas where such an equipment is used, such as high energy radiography, computer tomography, intraoperative surgery, neurosurgery, radiation therapy, geophysical logging, sterilization, space technology, and any other application for high energy X-ray or electron beam equipment.

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Development of Artificial Pinning Center Niobium-Titanium Superconductors with Very High Residual Resistivity Ratio Aluminum Stabilizers--Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545-3386; (508) 842-0174
Mr. Mark K. Rudziak, Principal Investigator
Ms. Elaine Drew, Business Official
DOE Grant No. DE-FG02-95ER82083
Amount: $75,000

A proven process for the manufacture of niobium titanium (NbTi) superconductors using an artificial pinning center (APC) approach has been developed. The process assembles alternate layers of Nb and Ti metals to form a superconducting filament through partial diffusion of the pure metals. One successful commercial version of this process utilizes a diffusion heat treatment in the monofilament stage and a moderate multifilament extrusion temperature. Such a process is amenable to the incorporation of a high purity aluminum (Al) core. The APC approach avoids the mechanical and interdiffusional problems associated with Al-cored composites when they are used with conventional NbTi alloy (which requires three to four precipitation heat treatments after the multifilament extrusion operation). The internal Al core also avoids the problem and expense of applying Al on the outside of long lengths of NbTi composite. The Al stabilizer offers much improved thermal and electrical conductivity compared to copper stabilizers. Improved conductivities allow magnet designers very stable, low mass magnets with lower overall stabilizer fractions which increase the field strength and/or decrease the magnet volume. In Phase I, the optimal processing conditions required for fabricating fine, uniform multifilament composites with different Al volume fractions will be determined. This effort will utilize the high critical current (J_c) APC monofilament previously proven in full scale HEP composites, and can incorporate improved APC materials in the future.

Anticipated Results/Potential Commercial Applications as described by the awardee: The technical objective of the Phase I effort is to understand how the multifilament extrusion process affects the filament uniformity in Al-cored APC NbTi composites with different Al fractions. This understanding will enable new low cost commercial superconductors to be fabricated which offer improved stability, reduced mass, and higher overall J_c as compared to copper-stabilized conductors.

HIGH ENERGY PHYSICS DATA PROCESSING AND DETECTOR INSTRUMENTATION

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A Three Dimensional Flow Parallel-Processing System for Fast Programmable Real-Time Applications--3D-Computing, 900 Hideaway Place, DeSoto, TX 75115-5213; (214) 341-0000
Mr. Dario B. Crosetto, Principal Investigator
Mr. James Lynn, Business Official
DOE Grant No. DE-FG03-95ER81905
Amount: $74,711

The 3D-flow processor system is a new concept that enhances the ability to provide high-speed, digital, programmable solutions to a broad spectrum of problems. Currently, systems of comparable speed are custom built with application specific integrated circuits that implement fixed algorithms, rendering them inflexible. The 3D-flow processor, in contrast, combines an innovative processor with an overall system architecture, which circumvents inflexibility and achieves a highly modular and incremently upgradable programmable system. The throughput of the system can reach one frame/clock cycle. With a processor clock speed of 100 MHz, the system can sustain a data processing volume at the rate of one frame every 10 nanoseconds for low resolution, high-speed images or sophisticated processing of very high resolution still images in real-time. During Phase I, the existing preliminary design of the processor will be completed. Detailed simulations of image processing algorithms on the 3D-flow will be conducted to evaluate system performance, and a report on commercial applications of the system along with cost-performance estimates will help designers make informed choices among the high-speed, real-time systems available.

Anticipated Results/Potential Commercial Applications as described by the awardee: This processor aims to solve fast, real-time problems. It offers advantages in pattern-recognition, real-time control, image processing, medical applications, and quality control in manufacturing. The planned system can provide low-cost solutions to applications ranging from those that fit on a personal computer board to large systems which require real-time data acquisition and processing up to millions of frames per second. The outcome of this research could benefit the Nation by providing better instrumentation for science, medicine, and commercial applications.

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An All-Digital, Multi-Hit Time-to-Digital Convertor Based on Superconductive Digital Counters--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523-1101; (914) 592-1190
Dr. Oleg Mukhanov, Principal Investigator
Dr. Elie K. Track, Business Official
DOE Grant No. DE-FG02-95ER81990
Amount: $74,926

Measuring the mass or energy of a particle by timing its flight path is a traditional technique in all branches of nuclear physics research. Time-to-digital converters (TDCs) are used to measure the time of flight of a particle. This project will develop an all-digital TDC with 10 ps time resolution and up to a 32-bit dynamic range. Because of the compactness of the planned TDC, multiple TDC channels will be implemented on a single integrated circut (IC) ensuring perfect mutual synchronization and sharing part of the hardware. The TDC consists of superconductive counters, shift registers, and pulse detectors. The operation of a 12-bit counter at over 100 GHz has already been demonstrated. The value of the counter is latched while the counter is operating at full speed. The TDC resolution is the maximum counter speed, or 10 ps for a 100 GHz clock rate. The full scale dynamic range is the length of the counter: for a 32-bit counter operating at 100 GHz (10 ps resolution) the dynamic range is 42 ms. The latched counter value can be stored into a first-in-first-out (FIFO) register integrated on the same IC. This TDC design allows for multiple hits on a single channel. The FIFO update rate is fast enough to acquire multiple trigger events from a single pulse of short duration. The timing of these multiple trigger points can provide the information required to calculate the pulse centroid. The output of the superconductive TDC will be accessible via a superconductor/semiconductor virtual machine environment-compatible interface. In Phase I, the ability to latch data from a counter while operating at high-speed will be demonstrated. A 12-bit high speed counter operating at 100 GHz and a 12-bit read-out latch will be integrated. The circuit will be tested by using a fast-edge signal to reset the counter and a delayed copy of the signal to trigger the read-out latch. The TDC resolution and code threshold transition statistics will be measured. In Phase II, a complete multi-channel single-chip TDC with on-chip FIFO will be developed.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of a compact, low-cost, all-digital TDC is expected to benefit all particle detectors that require a time-of-flight detector subsystem. The TDC will provide unprecedented resolution, dynamic range, and multi-hit capability while accommodating multiple channels per IC for the efficient implementation of large systems. The TDC will also improve the performance of military emitter detection finding and commercial modulation domain instrumentation.

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An Interleaved 10-bit Superconducting Flash Analog-to-Digital Converter with 2.5 Gigahertz Input Bandwidth--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523-1101; (914) 592-1190
Dr. Paul Bradley, Principal Investigator
Dr. Elie K. Track, Business Official
DOE Grant No. DE-FG02-95ER81986
Amount: $74,958

Until very recently, analog-to-digital converters (ADCs) have been unable to digitize frequencies in excess of 1-2 GHz. This limit has now been far exceeded by the development of a 6-bit ADC with a 10 GHz input bandwidth (the 3 dB roll-off point). It is capable of about 5 effective bits of resolution at 4 GHz input bandwidth and about 4 effective bits of resolution at 7 GHz input bandwidth. However, the resolution at GHz frequencies has been limited by dynamic distortions in the thresholds proportional to the input signal slew rate. To obtain higher resolution, a new comparator design has been simulated in which these distortions are cancelled by symmetry. Simulations of the new design at 10 GigaSamples/sec indicate an order of magnitude improvement in the aperture time of the ADC (0.5 ps - about 3 more bits of resolution at high frequencies) with 8 interleaved comparators. In Phase I, this project will determine the feasibility of a 10 bit ADC exhibiting at least 8 bits of resolution at 2.5 GHz and the best architecture to implement it. This will require matching inductors in the comparators and coupling transformers to one part in 1024. Phase II will consist of the design, fabrication, and testing of the full 10-bit ADC.

Anticipated Results/Potential Commercial Applications as described by the awardee: Fast 10 bit analog-to-digital converters may be used in wideband radar, high-speed signal acquisition in particle detectors, or a general purpose transient digitizer (i.e. digital oscilloscopes, etc.). A digitizer may be used for measuring any electronic signal, but its best use is to characterize very high speed events that occur rarely or at unpredictable times (e.g., the causes of errors in high performance electronics or optics could be diagnosed to reduce bit error rates).

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Real-Time Digital Error Correction for Improved Analog-to-Digital Conversion--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523-1101; (914) 592-1190
Dr. Steven Kaplan, Principal Investigator
Dr. Elie K. Track, Business Official
DOE Grant No. DE-FG02-95ER81987
Amount: $74,981

Development of a lower-power, ultra-fast, high-resolution flash analog-to-digital converter (ADC) for digitizing high-energy particle detector signals is planned. Niobium-based superconductive technology will be used to implement ADC comparators with an aperture uncertainty time of less than 250 fs, leading to a resolution of nine Effective Number of Bits (ENOB) at an input bandwidth of 2.5 GHz. This ADC has already demonstrated a resolution of 4.2 ENOB at four GHz, and low-speed operation of almost eight ENOB. However, many applications, including particle detection, require a 10-bit ADC. Present performance is limited by noise and clock skew in the ADC comparators for the more significant bits. The resulting threshold jitter causes coding errors. These errors can be corrected in real time by implementing a new ADC architecture using only the least significant bit thresholds to code the signal. Superconducting Rapid Single-Flux-Quantum (RSFQ) circuits will be used to select which of the two comparators for each ADC bit is farthest from the code threshold. The feasibility of these improvements will be demonstrated by designing, simulating, and testing the error-correction gates and circuits in Phase I. In Phase II, a complete ADC will be fabricated. A complete transient digitizer will be built and fielded in Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: The feasibility of a monolithic ADC with greater than nine effective bits of resolution at 2.5 GHz will be proven. This ADC could be applied wherever real-time signal processing is needed with wide dynamic range and low power. Many channels can be run simultaneously and economically. This approach will be useful in handling fast data streams from particle detectors, secure communications, and radar.

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A High Resolution Multi-hit Time to Digital Converter Integrated Circuit--LeCroy Research Systems Corporation, 700 South Main Street, Spring Valley, NY 10977-6499; (914) 578-6006
Dr. Mark Gorbics, Principal Investigator
Mr. Joseph Migliozzi, Business Official
DOE Grant No. DE-FG02-95ER82009
Amount: $71,402

By using a novel application of the Vernier principle, it is planned to construct a time measuring integrated circuit with a resolution of 50 picoseconds or less. This will be a pipelined, multihit device, capable of operating in common stop mode, with a double hit resolution of approximately ten nanoseconds, and maximum time range of 32 microseconds. This new variation of the Vernier technique will allow this device to be fabricated using a standard high speed digital composite metal oxide semiconductor process. Phase I covers the design and fabrication of a prototype test chip, and its evaluation.

Anticipated Results/Potential Commercial Applications as described by the awardee: This device has many potential applications in high energy and nuclear physics experiments, as well as other fields of research. The resolution will be comparable to the conventional analog time to amplitude converters currently used in these applications, with the added benefits of long time range, multihit capability, and common stop operation.

NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

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A Segmented Deep Depletion Depth Silicon Detector and Application Specific Integrated Circuits Signal Conditioning Systems for Physics Research--Intraspec, Inc., P.O. Box 4579, Oak Ridge, TN 37831-4579; (615) 483-1859
Mr. John Walter, Principal Investigator
Mr. John Walter, Business Official
DOE Grant No. DE-FG02-95ER82003
Amount: $75,000

In the past, oxide passivated silicon radiation detectors have been mostly limited to sensitive depths of less than one mm, with cost limitations making the practical limit for large scale applications closer to 0.5 mm. This project will develop affordable oxide passivated silicon (Si) detectors with sensitive depths in the range of one to three mm. An Application Specific Integrated Circuit (ASIC) signal conditioning technology, designed to optimize the performance of deep, low capacitance, low leakage current detectors, will also be developed. The Phase I technical objectives are to: (1) show that the oxide passivation process can be combined with a low nitrogen (N) silicon capability to produce good 35 mm diameter, totally depleted Si detectors with depletion depths greater than one mm; (2) explore methods of changing the oxide passivation process to make it compatible with low N material (including lower edge leakage currents, higher breakdown voltage, lower cross-talk between adjacent elements on a common wafer, and a possible improvement in the radiation hardness of the Si/SiO_2 passivation); (3) investigate the potential of a lift-off technology to reduce the detector fabrication costs for segmented detectors, and (4) develop an architectural plan for combining segmented Si detectors and improved ASIC signal conditioning chips.

Anticipated Results/Potential Commercial Applications as described by the awardee: The availability of oxide passivated deep Si detectors with dedicated ASIC preamplifiers will make an important contribution to radiation detection and spectroscopy applications in many diverse areas ranging from particle physics research to industrial x-ray spectroscopy.

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A Polarized (Spin Aligned) High Density Helium Gas Target--MetaStable Instruments, Inc., 1807 Vichy Road, Rolla, MO 65401-2248; (314) 453-0433
Dr. Edward Stephens, Principal Investigator
Dr. George Dube, Business Official
DOE Grant No. DE-FG02-95ER82025
Amount: $73,112

This project involves a compact and reliable apparatus for producing atmospheric pressure helium gas with spin aligned nuclei. This ensemble of spin aligned helium nuclei can be used to polarize (spin select) neutron beams for a variety of scientific and commercial applications. In Phase I the apparatus will be designed, assembled, and tested. Optical (laser) pumping at 1083 nm is used to produce spin alignment in a low pressure helium gas cell. A nonmagnetic diaphragm compression pump is then used to compress the helium gas to the higher pressures needed in a target or neutron spin filter. The pump and the entire gas transport system must be completely nonmagnetic to prevent depolarization of the spin aligned helium atoms. Nuclear magnetic resonance will be used to measure the polarization of the helium in both the low and high pressure cells. The difference in the polarization between the two cells is a measure of the depolarization produced by the helium compression system. The goal of the research is to experimentally confirm an that an existing nonmagnetic pump can produce high gas pressures without significantly depolarizing the helium.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result of this research is that spin aligned high-density helium gas targets will be developed and made available to interested Government laboratories and commercial customers for use in compact and reliable neutron spin filters, neutron scattering studies, magnetic resonance imaging, and other applications.

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Microporous Alumina Microchannel Plates--NanoSystems Inc., 29 Cambridge Circle, New Milford, CT 06776-3921; (203) 354-3668
Dr. Charles P. Beetz, Principal Investigator
Mr. Robert Boerstler, Business Official
DOE Grant No. DE-FG02-95ER82036
Amount: $74,987

Microchannel plates (MCPs) are essential for high gain imaging and detection applications in science, medicine, and industry. They have superior temporal resolution for incident charged and ultraviolet/x-ray beams, operate in high magnetic fields, and are essential for many particle detection applications in scientific instrumentation such as scintillating fiber particle trackers. However, most existing MCPs are fabricated from activated glass and suffer from a gain that falls rapidly with the cumulative charge per area collected from the MCP. Furthermore, MCPs are expensive, available in limited areas, have significant spatial non-uniformities, and are readily damaged by radiation. This project will overcome many of these difficulties by using anodized aluminum plates as the basis of an MCP. When formed under controlled anodization, amorphous alumina contains open, densely packed, straight micropores, oriented perpendicular to the surface, with a length to diameter ratio appropriate for microchannel gain. Pure alumina has a sufficient secondary emission gain so that the pores can serve as gain channels, without activation, or contaminating materials. It is anticipated that this ceramic material will have superior stability and lifetime properties compared to glass MCPs, very low cost, and the potential of large MCP areas. The microporous MCP matrix could result in much better spatial resolution and spatial uniformity than existing MCPs, and have greater radiation resistance. In Phase I, it is planned to fabricate prototype amorphous alumina MCPs by anodization, and measure gain, gain stability, and spatial properties.

Anticipated Results/Potential Commercial Applications as described by the awardee: The gain stability and long life will enable the fast, compact MCP technology to be used much more widely in a large variety of vacuum electronics amplification application: (1) ultrafast, gated, compact, high magnetic field, radiation-hard MCP photomultipliers; (2) long lived image intensifiers/converters with submicron spatial resolution; (3) flat panel vacuum phosphor displays; and (4) imaging charged particle/x-ray detectors with high gain and submicron spatial resolution.

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Novel Avalanche Photodiode Arrays for Ultraviolet Light Detection--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172-4624; (617) 926-1167
Dr. Stephan Vasile, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-95ER82061
Amount: $75,000

Cerenkov detectors are valuable tools for particle identification in nuclear physics research. Among their unique advantages are particle velocity determination with excellent resolution, mass discrimination of particles with the same momentum, selection of a component of high energy particles against an intense background of particles with subthreshold energies, and the direction of the particle trajectory. However, the Cerenkov detectors are limited by the resolution of the sensors used to detect the ultraviolet (UV) light emission following the Cerenkov interaction. A rugged, high UV sensitivity, two-dimensional detector array with improved radiation hardness will be developed, based on a new silicon avalanche photodiode (APD) array technology to be used in Cerenkov detectors. Phase I will be devoted to the redesign of an existing array to yield UV enhanced sensitivity, fabrication of the prototype APD array, and performance testing. Phase II will optimize the array, design and realize specific optical interfacing, test the radiation hardness performance, and implement the new array as a Cerenkov detector ring image reader. The advantages of the new two-dimensional detector are enhanced UV sensitivity, high internal gain of the APD, and enhanced position resolution. The silicon APD detector technology offers the potential for a unique photodetector which could replace standard photodiodes and photomultiplier tubes in many applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: APD arrays can improve today's state-of-the-art in UV detector technology and contribute to increased instrumentation sensitivity. This novel detector would offer a new high UV sensitivity, rugged, photon detector array for the nuclear physics research community. The resulting detector would find widespread use in high energy physics, materials science, biomedical research, and astronomy.

83

Cesium Iodide Bromide and Cesium Iodide Chloride Scintillators for High-Rate Applications--Rais Enterprises, Inc., 6393 Nancy Ridge Drive, #B, San Diego, CA 92121-2247; (619) 452-0500
Dr. Emmanuil Raiskin, Principal Investigator
Dr. Emmanuil Raiskin, Business Official
DOE Grant No. DE-FG03-95ER82062
Amount: $74,564

The overall goal of this program is to develop a production method and optimal composition for CsIBr (cesium iodide/bromide) and CsIC1 (cesium iodide/chloride) scintillators for high-rate applications. The fast emission of light for pure CsI is well known. However these emissions are generated at ~305 nm. For this reason, light collection needs the use of photomultiplier tubes (PMT) with quartz windows, which significantly increases the cost of experiments. Experiments conducted in the former USSR show that partial substitution of the anion (I) in CsI crystals to the Br or C1 will increase the wavelength of the emitted light with very little change in the decay constant. This makes possible the collection of light with regular PMT. In Phase I, this project will evaluate the application of the horizontal Bridgman method combined with zone refining for the production of CsIBr and CsIC1 scintillators for high-rate application.

Anticipated Results/Potential Commercial Applications as described by the awardee: Development of the technology for production of CsIBr and CsIC1 scintillators will increase the capabilities of nuclear physics experiments. It is possible that these fast scintillators will find an application in positron emission tomography. Also the horizontal Bridgman method is expected to improve the quality and reduce production costs for CsI(T1) which is now grown by the vertical Bridgman method.

84

Low-Cost, Large-Area, High-Resistivity Substrates for Gas Microstrip Detectors--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Rengarajan Sudharsanan, Principal Investigator
Mr. Richard S. Gregorio, Business Official
DOE Grant No. DE-FG02-95ER82073
Amount: $74,800

This project will develop low-cost, large-area, high-resistivity substrates for gas microstrip detectors (GMDs), a variation of the multi-wire proportional counter. These detectors, whose electrodes are patterned on large-area glass or polymer substrates, require a surface resistivity in the 10^{13} to 10^{14} ohm per square range to dissipate charge collected on the dielectric. To achieve this resistivity, the substrate will be coated with a thin cadmium zinc telluride (CdZnTe) layer of appropriate thickness and Zn content. In Phase I CdZnTe thin films with various Zn compositions will be deposited on glass and plastic substrates by metalorganic chemical vapor deposition. As-deposited films will be characterized for adhesion, thickness, Zn composition, and electrical resistivity. An interdigitated pattern, formed on the coated substrates by photolithography, will permit sheet resistivity measurements and demonstrate good ohmic contact to the surface. A GMD design optimized to exploit the potential of the new substrate material during a Phase II project will also be developed.

Anticipated Results/Potential Commercial Applications as described by the awardee: If successful, this effort will produce inexpensive, large-area, electrically resistive substrates for GMDs which represent the next generation of large area detectors for nuclear and heavy ion physics, high energy physics, and synchrotron radiation imaging. In addition, they are applicable to medical radiography, advanced lithography, and surface characterization.

NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

85

A High Power High Frequency Transistor--
Astralux, Inc., 2386 Vassar Drive, Boulder, CO 80303-5763; (303) 494-0670
Dr. Jacques I. Pankove, Principal Investigator
Dr. Ethel Pankove, Business Official
DOE Grant No. DE-FG03-95ER81928
Amount: $75,000

This project involves building a compact, rugged, long-lasting solid state device capable of amplifying a high frequency signal with a gain of 30 db at 1.5 GHz. The new device consists of two temperature resistant materials gallium nitride (GaN) and silicon carbide. The wider bandgap GaN serves as the emitter. The difference in bandgap between the emitter and the base blocks the escape of holes from the base, thus achieving record high electron injection efficiency. A current density of 1.8 KA/cm^2 and a power density of 30 KW/cm^2 have been obtained. This transistor has operated at 535°C with a current gain of 100. Although the transit time of electrons through the base is on the order of a picosecond, the frequency response of this device has not been measured. During Phase I, the resistive-capacitive time constant of the emitter-base circuit will be measured and the frequency response determined.

Anticipated Results/Potential Commercial Applications as described by the awardee: The commercial potential for this high-risk project is enormous. A high power, high-frequency transistor is of interest for the following commercial applications: broadcast transmitters, cellular phones, and radar. Other applications that may benefit from the heat resistance or the materials used in the new transistor are microwave ovens, induction heaters, radiofrequency furnaces, and plasma generators.

86

Manufacturing Technologies, Improved Performance, and Cost Reduction of Superconducting Radiofrequency Resonant Niobium Cavities--
Atlas Technologies, Inc., 2760 Washington Street, Port Townsend, WA 98368-4615; (360) 385-3123
Mr. Richard D. Bothell, Principal Investigator
Mr. Richard D. Bothell, Business Official
DOE Grant No. DE-FG03-95ER81930
Amount: $74,994

In recent years radiofrequency superconductivity has surged to become an important technology in the construction of new particle accelerators. Current technologies used to fabricate the resonant superconducting radiofrequency (SRF) niobium chambers for the Continuous Electron Beam Accelerator Facility require extensive electron beam welding at critical locations that effect the performance of the cavity. The most notable welds occur at the equatorial and the iris regions where the electric and magnetic fields are at the maximum. The goal of this project is to eliminate these welds with a cost effective explosive forming technique. Phase I proof of concept will form a niobium tube into a resonant cavity. If this forming process proves feasible, a second copper/niobium composite tube material will be explored for forming. Such a development offers the possibility of cost reduction by reducing the amount of superconducting grade niobium (current design uses 35 lb at $200/lb). In addition to materials savings, it is expected that a copper-sheathed niobium cavity will exhibit better thermal performance by rapidly removing internally generated heat, thus thermally stabilizing the super-cooled superconducting niobium. Accelerator cavities must be connected to a ultra-high vacuum system and to the radiofrequency source. A further study will explore a flange connection system for accelerators. An ultra-high vacuum bi-metal flange capable of cryogenic cycling to 2 K will be studied. It is anticipated that explosive bonding of titanium to niobium, which share similar coefficients of thermal expansion, can be accomplished. A knife-edge seal will be fabricated on the harder titanium side of the flange, and the niobium side will then be welded to the cavity. This bi-metal flange technology has already been employed using a stainless steel to aluminum combination

Anticipated Results/Potential Commercial Applications as described by the awardee: This research intends to improve the performance and lower the costs of SRF resonant cavities. A high performance, lower cost cavity technology can serve many present and planned accelerator projects located in the United States, Europe, and Asia. In addition to serving the high energy physics field, these cavities can become vital components for the emerging technology of free electron lasers (FEL). Industrial application of FEL offers high-powered, wavelength-tunable light sources for advanced surface processing of polymers, composites and metals.

87

Forty Gigahertz Acquisition of Bunch Profile, Position, and Arrival Time for Particle Accelerator Diagnostics and Control--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523-1101; (914) 592-1190
Dr. Steven Kaplan, Principal Investigator
Dr. Elie K. Track, Business Official
DOE Grant No. DE-FG02-95ER81988
Amount: $74,952

This project will develop a low-power 40 GHz acquisition system for real-time measurements in nuclear and high-energy particle accelerators. The following parameters will be monitored: (1) beam current profile captured at 40 gigasamples per second (GS/s) with six bits of resolution, (2) bunch time of arrival to 25 ps relative to a synchronized master clock, and (3) beam position to 25 microns. The planned digitizer is based on a superconducting 6-bit 40 GS/s flash analog-to-digital converter (ADC), superconducting acquisition memory buffers, and pickup coils along the beam axis. One digitizer will sample the current induced in a pickup coil by the beam current. Two more identical digitizers, connected to differential X- & Y-axis pickup coils, will measure the change in position of the beam current bunch with a 25 μm resolution every 25 ps. A separate circuit will measure the bunch time of arrival with 25 ps resolution and generate a time stamp. The beam profile and position is acquired continuously until a trigger event is generated by threshold level detection of a beam bunch, resulting in a snapshot of the last 24 samples in memory. The data are read out from another shift register, then stored in external memory for analysis. The projected size of the complete digitizer chip would be one cm^2 and will dissipate several mW. The cost for multiple niches in a large accelerator is estimated to be about $2000 per niche. The Phase I project objective is to demonstrate the high speed performance of the flash ADC and its acquisition storage.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned system will allow a precise monitoring of the beam characteristics of nuclear particle accelerators such as a relativistic heavy ion collider. This system performs functions that are currently unattainable (40 GS/s digitization) with low-power (less than 1 mW) and small size (less than 1 cm^2). The ability to measure the profile, position, and time of arrival of every bunch in real time should prove invaluable during start-up and operation of a nuclear or high-energy particle accelerator.

88

A High Brightness Cold Cathode Electron Beam Source--NZ Applied Technologies, Inc., 150-C New Boston Street, Woburn, MA 01801-6204; (617) 935-2030
Dr. H. Paul Maruska, Principal Investigator
Dr. Peter E. Norris, Business Official
DOE Grant No. DE-FG02-95ER82044
Amount: $74,994

Electron accelerator cavities are being developed for systems such as the Continuous Electron Beam Accelerator Facility which require very high brightness electron beam sources. Such an electron beam source would also be valuable for many other commercial instruments such as electron microscopes and electron beam lithography equipment. For many of these applications, the requirements exceed the capabilities of presently available thermionic cathode models. The goal of this Phase I project is to develop new electron-emitting cathodes which exhibit improved levels of performance. These cathodes will be based on nitride semiconductors which can exhibit zero or negative electron affinity. Therefore, the potential barriers to electron flow across the surface of the cathode would be low or non-existent. Because the electric field required to extract electrons from a cold cathode is strongly dependent on the amplitude of the surface potential barrier, enormous fields are required to overcome materials limitations. Consequently, few practical cold cathode sources have ever been developed. The development of a material with an electron affinity approaching zero is critical for the operation of a cold cathode with practical electric fields. However, the lack of a source of mobile electrons within such a cathode can be equally limiting, since the materials in question are not metals but insulators. A materials approach will be employed to develop a new cathode structure which will allow electrons to be transferred from a high capacity reservoir to the emitting surface through a unique energy ladder based on a quantum mechanical tunneling concept. The field emission cathodes are very promising because they appear capable of delivering high current densities while functioning at room temperature, giving the potential of long term stability. Nitride materials incorporating an energy ladder should lead to a new generation of extremely bright, robust, electron sources.

Anticipated Results/Potential Commercial Applications as described by the awardee: The goal of this project is to develop a cold cathode field-emitter exhibiting such a high brightness electron beam that it eclipses conventional thermionic and photo-emission sources. A high brightness electron source will find Government and commercial applications in the development of free-electron lasers, accelerators, high-power traveling wave tubes, and electron-bombarded semiconductor amplifiers.

PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

89

Development of a Multi-Stage Depressed Collector for a One Megawatt Continuous Wave Gyrotron--Calabazas Creek Research, 20937 Comer Drive, Saratoga, CA 95070-3753; (408) 867-4116
Dr. R. Lawrence Ives, Principal Investigator
Dr. R. Lawrence Ives, Business Official
DOE Grant No. DE-FG03-95ER81937
Amount: $75,000

It is estimated that the maximum interaction efficiency that can be achieved in one MW gyrotrons producing quasi-optical radiofrequency power above 100 GHz is less than 40%. The most effective way to increase the total efficiency is to use a multi-staged depressed collector to recover power from the spent electron beam. This project will develop a multi-stage depressed collector for quasi-optical gyrotrons capable of increasing the over-all efficiency to more than 50%. The energy spectrum from the spent electron beam from a gyrotron will be analyzed to design a two stage depressed collector. Careful attention will be given to performance, reliability, availability of materials, manufacturability, and cost. Research will also be performed to minimize reflected primary electrons and secondary electron emission by careful electrode design and surface coatings. Initial efforts will concentrate on a two-stage design with investigation of additional stages for increased efficiency. Specifically, the Phase I project will develop a preliminary design for a two-stage depressed collector for a one megawatt, continuous wave gyrotron at 170 GHz. The design is expected to increase overall tube efficiency to more than 50% and will address issues related to secondary emission, reflected electrons, power supplies, cooling, manufacturability, and cost.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that the planned research will result in the design of a two stage depressed collector for a gyrotron that will increase the overall efficiency of the device to more than 50%. The design technology developed will be applicable to gyrotrons utilizing quasi-optical output modes.

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Development of a One Megawatt Continuous Wave Waterload for Gyrotrons with a Gaussian Output Beam--Calabazas Creek Research, 20937 Comer Drive, Saratoga, CA 95070-3753; (408) 867-4116
Dr. R. Lawrence Ives, Principal Investigator
Dr. R. Lawrence Ives, Business Official
DOE Grant No. DE-FG03-95ER81938
Amount: $75,000

In order to test high power gyrotrons, it is necessary to dissipate the output power into an RF load. Research efforts are under way to develop 1 MW CW (continuous wave) gyrotrons for electron cyclotron resonance heating and current drive in tokamaks. In Phase I, this project will develop a waterload capable of dissipating 1 MW of continuous power from gyrotrons RF output between 100 and 200 GHz in a quasi-optical mode. The device will be designed to provide RF frequency and power measuring diagnostics as well as viewports for infrared window monitoring systems. Internal surfaces will be mechanically adjustable to accommodate small beam misalignment and optimization of the power distribution on the internal loss structures. The device will be capable of vacuum or pressurized operation. The goal is to develop a waterload that is reliable, safe, and easy to install and operate by the end user of the gyrotron.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is expected that this project will develop a 1 MW CW waterload easily installed and operated by the end user of the gyrotron. The device will be applicable for quasi-optical gyrotrons in the 100-200 GHz frequency range and will be adjustable for optimizing the optical and thermal performance. The device will support infrared window monitoring equipment and diagnostics for measuring output power and frequency. It will be available to institutions engaged in fusion energy research.

91

A High Conductance Thermal Interface--Energy Science Laboratories, Inc., 6888 Nancy Ridge Drive, San Diego, CA 92121-2232; 619-552-2034
Dr. Timothy R. Knowles, Principal Investigator
Dr. Timothy R. Knowles, Business Official
DOE Grant No. DE-FG03-95ER81967
Amount: $75,000

The interface between plasma-facing armor tiles and the vessel wall presents a critical thermal control problem in tokamak reactors. During high-heat-flux operation the tiles curl slightly, causing severe thermal impedance in the vacuum gap region. High surface temperatures lead to lower armor lifetime. A high conductance compliant interface is required that is compatible with the tokamak environment and remote handling limitations. This project investigates an interface concept in which carbon fiber brush structures are mounted on both of the mating surfaces. These brushes interpenetrate when the tile is mounted, forming an interface with large effective area and small effective gap. The interface remains effective even if the tile curls. Numerous fiber-fiber point contacts are formed. The interface does not require contact pressure and operates in a vacuum as well as in a wet environment. No tokamak-incompatible materials are required. Phase I is aimed at demonstrating the feasibility of high conductance vacuum interfacing compatible with remote handling in tokamak fusion reactors. A matrix of interface test articles will be fabricated and tested for heat transfer in a vacuum using the cut-bar method. The joining and separation behavior will be studied to identify methods suitable for robotic operation. Cost-effective fabrication methodology will be pursued.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project should lead to improved plasma confinement, reduced armor temperature, and reduced risk of carbon fire in an accident. High conductance interfaces have wide application in the thermal management of electronics and power systems.

92

Low Cost, High Conductivity Plasma Facing Components--Fiber Materials, Inc., 5 Morin Street, Biddeford, ME 04005-4497; (207) 282-5911
Dr. Clifford F. Baker, Principal Investigator
Mr. David R. Audie, Business Official
DOE Grant No. DE-FG02-95ER81970
Amount: $74,934

Carbon-carbon composites have demonstrated their superiority over monolithic graphites when used as plasma facing components in fusion reactors. Extensive use in both the Tokamak Fusion Test Reactor and the Joint European Torus have resulted in improved reactor performance. Next generation fusion reactors, such as the Tokamak Physics Experiment (TPX) will place even greater demands on the plasma facing components (PFCs) so that improved carbon-carbon composites having higher conductivity will be required. Unfortunately, these high conductivity carbon fibers are also very expensive, making the composites very expensive as well. A low cost composite, with similar properties, is required to make PFCs a cost effective component in fusion reactors. Low cost carbon-carbon fabrication is possible if low cost carbon fibers, which can be converted to high performance fibers during composite processing, are used. Recent developments in fiber technology make this a practical reality. With the high temperature heat treatment of standard carbon-carbon processing, the fiber properties will be improved at no extra cost to the manufacturing process. A project has been designed to demonstrate the fabrication of high performance carbon-carbon from low cost fibers, resulting in cost savings of 50% or more. In Phase I various carbon fibers will be evaluated to determine the effect of heat treatment on thermal and mechanical properties. The results of this evaluation, along with fiber cost, will be used to select the most promising candidates for further evaluation in carbon-carbon composites. A model for determining thermal conductivity in carbon-carbon composites will be developed and verified against the data measured in the project.

Anticipated Results/Potential Commercial Applications as described by the awardee: A well characterized, low cost, high conductivity carbon-carbon will result in large savings to projects like TPX that require high performance PFCs. A low cost material will also have applications in thermal management, particularly in weight sensitive satellites and state-of-the-art, high power semiconductor systems. As high conductivity is directly related to high fiber modulus, weight critical structural applications where stiffness is important will also benefit from the lower cost.

93

Structure-Property Relationships of Internal-Tin Niobium Tin--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06704-1039; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-95ER81992
Amount: $75,000

Two different strand designs of Nb$_3$Sn (niobium/tin) conductor have been made, both meeting the International Thermonuclear Experimental Reactor (ITER) specifications under most conditions. The main difference in the designs is the diameter of the filaments. Property variability has, however, been experienced in one of these designs. In order to explain this variability, it is important to understand more thoroughly the factors affecting these properties. Once this understanding is obtained, it will then be possible to make design changes to minimize the effects in a logical and scientific manner. This project will make relatively basic diffusion, dilatometric and metallographic studies on specially prepared samples, and also study the parameters affecting critical current density and losses. An examination will be made of methods of reducing bridging, varying ramping conditions, and the effects of these changes on structure. Once a better understanding of the behavior of these materials is obtained in Phase I, Phase II will be concerned with the design of new improved conductors for a range of applications. These could involve, fusion, high energy physics, high field laboratory magnets and even magnets for nuclear magnetic resonance investigations.

Anticipated Results/Potential Commercial Applications as described by the awardee: This work will result in the development of a family of improved, low loss Nb$_3$Sn materials for magnets to be used in high field pulsed or high ramp rate applications. At the present time, most of the demanding requirements arise in the fusion energy research area. One such possible application would be the inner windings of the ITER central solenoid coil.

94

A High Power Electron Gun--Omega-P, Inc., 202008 Yale Station, New Haven, CT 06520; (203) 458-1144
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG02-95ER82048
Amount: $75,000

This project deals with the feasibility of a new electron gun concept. The new gun could find use in multi-megawatt radiofrequency (rf) sources to be used with future tokamaks, including the International Thermonuclear Experimental Reactor, for plasma heating, current drive, and instability control. Present gyrotrons using magnetron injection guns (MIGs) encounter limited efficiency and mode competition because of poor beam quality from the MIGs. The new gun promises substantially improved beam quality, based on preliminary simulation studies. Analysis, computation and design are to be carried out in Phase I. The planned configuration employs a center-post space-charge limited injection gun that produces a convergent laminar-flow annular beam with low axial velocity spread. Transverse energy is to be imparted to this annular beam using cyclotron autoresonance acceleration in a cylindrical waveguide with an axially-tapered guide magnetic field to maintain resonance during acceleration. Selective detuning away from exact resonance provides minimum speeds in particle momentum and phase. Simulations indicate that a 6.4 MW, 320 kV annular beam with velocity ratio of 1.5 can be produced in this way that has an axial velocity spread of the order of only one percent. Point designs are to be devised for guns to be built and tested in Phase II that would be applicable for a 170 GHz multi-megawatt cavity source, and for a highly gyroharmonic converter in the 100 to 300 GHz range.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful designs and tests for the novel electron gun in Phases I and II could allow multi-megawatt continuous wave gyroharmonic devices to be built in the 100 to 300 GHz range that would overcome limitations of conventional cavity gyrotrons. This would allow efficient rf sources to be built for tokamak heating and current drive, electron-positron colliders, power beaming, materials processing, below-ground prospecting, radar, and communications.

95

Fabrication of a Flexible Reacted Niobium Tin Cable for Applications in React and Wind Magnets--Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545-3386; (508) 842-0174
Mr. Kenneth DeMoranville, Principal Investigator
Ms. Elaine Drew, Business Official
DOE Grant No. DE-FG02-95ER82082
Amount: $74,979

This project involves a novel technique for the fabrication of a flexible niobium tin (Nb_3Sn) cable in conduit conductor (CICC) suitable for a react-and-wind approach in the production of large superconducting magnets. The advantages of the react-and-wind over the more conventional wind-and-react approach are numerous and perhaps exist in every engineering aspect of the fabrication of CICC superconducting magnets. The technique discussed here is distinguished from other CICC react-and-wind approaches (where the CICC is first made, and then reaction takes place) by the innovation that the cable will be produced by using reacted Nb_3Sn strands. Therefore, the conduit can be applied to a reacted cable eliminating all issues regarding the heat treatment of a conduit that occur in other approaches. The keys to this method of fabrication of flexible Nb_3Sn cables are: (1) to use thin Nb_3Sn strands, and (2) to combine the Nb_3Sn strands with pure copper (Cu) wires. The goal of Phase I is to fabricate a 285 strand hybrid cable composed of superconducting strands and pure Cu strands, and to study its superconducting and mechanical properties by both experimental and analytical methods. For this preliminary cable, Nb_3Sn and Cu strand diameters will be identical, and the Cu to Nb_3Sn volume ratio will be kept constant at 2/1.

Anticipated Results/Potential Commercial Applications as described by the awardee: The surface to volume ratio of Nb_3Sn strands scales inversely with the diameter, and, therefore, cooling of the thin strands would be an order of magnitude larger than it is for the strands normally used in conventional CICC. There are significant economic advantages to this process. High field accelerator and fusion magnets can be fabricated using react-and-wind technology.

96

Fabrication of Copper-Backed Dense Tungsten Plasma Facing Component Armor--Surmet Corporation, 33 B Street, Burlington, MA 01803-3406; (617) 272-3250
Dr. Suri A. Sastri, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-95ER82085
Amount: $75,000

Tungsten, beryllium and carbon-carbon (C/C) composites have been identified as leading candidates for plasma facing component (PFC) materials in the International Thermonuclear Experimental Reactor (ITER). The combined high heat/neuton flux faced by the PFCs necessitates active cooling. While C/C and beryllium are preferred because of their low atomic number, tungsten is chosen because of its high melting point and resistance to sputter erosion. The development of a suitable technology for the PFCs to be thermally bonded to the cooling structure metals, notably to copper, is critical to the successful development of ITER. Several methods are possible but the joining of copper to tungsten is difficult because of the high stresses caused by the vastly dissimilar thermophysical and thermomechanical properties of these two metals. Phase I will evaluate the feasibility of fabricating a dense equiaxed tungsten PFC armor bonded to a copper backing starting with high purity elemental powders. The fabrication process will also allow the incorporation of a coefficient of thermal expansion (CTE) transition zone between the tungsten and the copper. This transition zone will have a graded structure. The process to be used can be described as a pseudo hot isostatic forge consolidation' technique. It is a rapid process and will produce a near net shape high density tungsten/copper composite tile. The microstructure of the tungsten is expected to be equiaxed and fine grained which should translate into high thermal conductivity and high thermal shock resistance properties in the fabricated tile. The copper backing will allow convenient bonding to the cooling structure of ITER. The planned tile, because of its unique structure, is expected to accommodate the large thermomechanical stresses arising out of exposure to a variety of thermal and mechanical stress conditions in the fusion environment.

Anticipated Results/Potential Commercial Applications as described by the awardee: The ability to successfully fabricate tungsten to near net shape components from elemental powder will be a significant development for fusion as well as magnetohydrodynamics. Emerging applications for tungsten bonded to copper occur for electronic packaging, for CTE matching, and for thermomechanical stress management. The dual function fabrication technology has high potential for market applications in both heavy industries and the consumer markets such as sports equipment. Biomedical x-ray anode applications could also benefit.

97

Low Temperature Fabrication of Copper Swirl Tubes for the International Thermonuclear Experimental Reactor--Surmet Corporation, 33 B Street, Burlington, MA 01803-3406; (617) 272-3250
Dr. Suri A. Sastri, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-95ER82084
Amount: $75,000

In the conceptual design of the International Thermonuclear Experimental Reactor (ITER), the first wall structure facing the plasma is the area that will experience the harshest environment. The number of engineering materials with properties required for this type of service is very limited. As currently designed, the first wall of ITER incorporates stainless steel as the structural material with overlaid copper alloy as a heat sink for the surface heat flux of the plasma facing component. High pressure coolant will be circulated through this cooling structure to extract the heat. High strength copper alloys are expected to be used in many of these critical thermal management applications. In the fabrication of the copper structures for ITER, there will be the need for joining one copper component to another. Of many such configurations, the design and fabrication of copper 'swirl tubes' is necessary for efficient and rapid heat removal from the high heat flux surfaces. In this design a 'swirl tape' or 'swirl foil' is intimately bonded to the interior wall of the cooling tube so as to provide efficient and rapid heat transfer from the tube structure to the cooling fluid. High thermal conductivity braze joining is the ideal way to accomplish this bonding of the swirl tape to the copper cooling tube. In Phase I, an innovative and simple low temperature joining process that can provide excellent joints with the required thermomechanical properties will be evaluated. This process is expected to be ITER-compatible in terms of neutron activation, high vacuum requirements, and corrosion resistance.

Anticipated Results/Potential Commercial Applications as described by the awardee: Copper to copper brazing using alloys that are free of silver and gold is critical to the successful development of tokamak reactors. Outside of the fusion program, the ability to braze high strength copper alloys at low temperature is a significant development with great commercial potential. Retention of materials properties after brazing will make these copper alloys more useful. The technique can also be extended to the joining of ceramics to metals.

98

A Discontinuous Fiber Composite Interlayer for Increased Brazed Joint Reliability--Technical Research Associates, 2257 South, 1100 East, Salt Lake City, UT 84106-2379; (801) 485-4991
Dr. Jared L. Sommer, Principal Investigator
Mr. Charles D. Baker, Business Official
DOE Grant No. DE-FG03-95ER82092
Amount: $75,000

The first wall structures of future fusion reactors will need to consist of graphite or carbon/carbon composite to withstand the high temperatures generated by the reacting plasma and fusion process. One proposed configuration is to braze the graphite material directly to an active-cooled copper substrate. Because of the dissimilar thermal and physical properties of the joined materials, high stresses occur in the brazed joint region if the two materials are joined at high temperature or if the brazed joint is placed under mechanical stress. These stresses are particularly high near the free edges of the brazed joint interfaces after cooling from the brazing temperature. In Phase I, a composite interlayer, composed of randomly dispersed graphite fibers within a pure copper matrix, will be incorporated between graphite material and copper substrate. This interlayer will act as a "functionally gradient interface" and provide a transition zone to progressively equalize the stress caused by the thermal mismatch. The coefficient of thermal expansion of the interlayer will be isotropic and tailorable, and it will potentially exhibit a high through-thickness thermal conductivity.

Anticipated Results/Potential Commercial Applications as described by the awardee: Brazed joints incorporating the discontinuous fiber interlayer should offer good mechanical and thermal properties. As a result, the brazed joints should be useful in components subjected to high heat loads such as diverters or limiters in fusion reaction systems. The commercial benefit of the proposed coating technology is potentially great. The discontinuous fiber composite can be used as heat sink material for electronic applications, due to the ability to tailor the thermal expansion and conductivity of the material.

99

A Helium-Cooled Faraday Shield Using Porous Metal Cooling--Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601-4794; (717) 569-6551
Mr. John H. Rosenfeld, Principal Investigator
Mr. Donald M. Ernst, Business Official
DOE Grant No. DE-FG02-95ER82095
Amount: $74,929

A helium-cooled Faraday shield should eliminate shutdowns for water clean-up caused by water-cooled tube failures. In a tokamak fusion reactor, the Faraday shield is located between the radiofrequency (rf) antenna and the plasma. The heat absorbed by the shield is a by-product of rf heating of the plasma and radiation from the heated plasma. Currently, water flowing through U-shaped shield tubes is used to cool the Faraday shield. If the water leaks into the reactor, many days can be required for cleaning and waste disposal. However, this problem can be avoided by using helium-cooled shield tubes. The challenge presented by gas cooling is to accomplish efficient heat transfer with relatively inefficient gas coolants. Porous metal cooling has demonstrated this capability in recent work. In the planned Phase I project, a full-scale helium-cooled porous metal heat exchanger (PMHX) Faraday shield will be designed

for removing the heat absorbed by the shield. The goal of the Phase I effort will be to demonstrate the capability of a helium-cooled PMHX shield tube to operate at the required heat loads (up to 4650 W) and heat fluxes (up to 200 W/cm^2) of a single Faraday shield tube. In Phase II, a proof-of-concept helium-cooled PMHX Faraday shield will be developed based on the Phase I full-scale PMHX shield design. The capability of the proof-of-concept PMHX shield will be demonstrated using an rf antenna to simulate the required heat loads and heat fluxes.

Anticipated Results/Potential Commercial Applications as described by the awardee: The goal of Phase I will be to demonstrate the capability of a proof-of-concept helium-cooled PMHX to operate at high heat loads and heat fluxes. Several applications for this technology include high energy beam dumps, plasma-facing components, laser diodes, vacuum tube components, high power optics, and gyrotron cavities.

FUSION ENERGY SYSTEMS

100

A Volumetric Neutron Source for Fusion Nuclear Technology Development--Energy Applications and Systems, Inc., 3198 Camino Arroyo, Carlsbad, CA 92009-7612; (619) 753-3488
Dr. Nicholas A Krall, Principal Investigator
Mr. S. Locke Bogart, Business Official
DOE Grant No. DE-FG03-95ER81965
Amount: $75,000

There is an emerging view that fusion programs need a volumetric neutron source (VNS), operating in conjunction with the International Thermonuclear Experimental Reactor (ITER), to test, develop, and qualify fusion nuclear technology components and material combinations for the Fusion Power Demonstration Reactor. The VNS will: (1) be a reliable source of about 100 MW of fusion neutrons, (2) have a blanket test area exceeding 10m^2, (3) operate for extended periods of time, (4) be highly maintainable, and (5) have a relatively low capital and operating cost. The VNS will be a tokamak since this approach is the only known magnetic confinement concept that is guaranteed to produce the required fusion neutron flux and fluence. It will be a small, driven machine to minimize costs. It will be based on a normally-conducting toroidal magnet set having joints to enable machine maintainability. Finally, it will be based on plasma geometries that have been shown to possess the performance required for the VNS. The Phase I project will attempt to meet the above characteristics by selecting the best design point to maximize fusion power at minimum cost and risk. The plasma operating point and geometry will be selected to minimize the risk of inadequate current drive and divertor performance. A technology effort will focus on the critical areas of current drive and the divertor, and will identify and characterize the development necessary for successful VNS operation. An engineering and design effort will focus on the toroidal magnet set to assure that it offers maximum VNS mission capabilities and does not constrain VNS performance.

Anticipated Results/Potential Commercial Applications as described by the awardee: VNS applications other than those for fusion programs will be reviewed and characterized. The project will focus on the production use of industrial isotopes for new applications and the use of the VNS for materials research. For completeness, an updated annotated bibliography of fusion applications for the fission fuel cycle will be provided.

101

Nondestructive Characterization of Radiation Embrittlement in Fusion Structural Materials Using Laser Ultrasound--Karta Technology, Inc., 1892 Grandstand, San Antonio, TX 78238-4507; (210) 681-9102
Dr. Satish Nair, Principal Investigator
Dr. G.P. Singh, Business Official
DOE Grant No. DE-FG03-95ER82107
Amount: $75,000

Neutron irradiation effects on structural materials is a critical issue challenging the designers of divertor, first wall, and blanket components for fusion reactor projects such as the International Thermonuclear Experimental Reactor (ITER) and the Tokamak Plasma Experiment (TPX). Neutron irradiation severely embrittles the materials, limiting the integrity and operational life of these structures. There is a need to both model and characterize the damage effects induced by radiation so that the materials can be qualified for use in fusion structures. Conventional methods for characterizing radiation damage are destructive and do not provide the capability of monitoring the material condition in situ. A novel ultrasonic method is planned which uses the linear and non-linear characteristics of acoustic waves to non-destructively detect changes in the fracture toughness of irradiated materials. During Phase I, the laser-based generation and detection of different ultrasonic parameters will be demonstrated in order to evaluate their sensitivity to fracture toughness. An innovative fiber-optic-based system will be developed during Phase II for the in-situ, nondestructive monitoring of material condition and characterization of radiation damage.

Anticipated Results/Potential Commercial Applications as described by the awardee: Development of nondestructive methods for radiation damage characterization will be of considerable benefit to designers of fusion reactor components to compare activation properties of different materials and enable better material selection. These systems can also be applied to monitoring the material condition in situ when the reactors are commissioned. Benefits extend to monitoring embrittlement in operating fission reactors, thus providing service life extension. Other potential industrial applications include the monitoring of temper-induced and hydrogen-induced embrittlement nondestructively.

102

Low Cost Fabrication of Large Silicon Carbide/ Silicon Carbide Composite Structures--Lanxide Corporation, P.O. Box 6077, 1300 Marrows Road, Newark, DE 19714-6077; (302) 456-6320
Dr. David V. Miller, Principal Investigator
Dr. Christopher Kennedy, Business Official
DOE Grant No. DE-FG02-95ER82008
Amount: $74,966

The objective of the planned effort is to develop and demonstrate an innovative approach for fabricating large structural components for fusion reactors. Silicon carbide fiber reinforced silicon carbide matrix composites will be produced by repeated infiltration and pyrolysis of fiber lay-ups with a novel preceramic polymer, CERASET™ SN. This polymer is considerably more advantageous to use than other known commercial or developmental preceramic polymers in that it is solvent free and thermosetting, and features low viscosity, high purity, and excellent stability in ambient atmospheres. Further, the CERASET™ SN preceramic polymer is inexpensive and available in large quantities. Innovative infiltration processes will be used to fabricate panels for test and evaluation. For each infiltration process, the maximum achievable fiber volume loading and minimum number of required densification cycles will be determined. The infiltration processes will be compared in terms of the physical and mechanical properties of the fabricated panels, fabrication cost, and ability to form large structural parts with complex geometries.

Anticipated Results/Potential Commercial Applications as described by the awardee: Numerous commercial industrial applications for fiber-reinforced carbide matrix composites exist: stationary high temperature gas turbine internal combustion engines (combustors, liners, turbochargers, glow plugs, valves, piston rings, heads, vanes, nozzles turbine rotors), heat recovery systems (tubes, supports, internals for air preheaters and recuperators), burners and combustors (radiant tube burners, catathermal combustors), waste incineration systems (conveyors, compactors, shredders, refractories, burners, rotary drums, tubes, ash plows, filters, scrubbers, sensors), separation and filtration systems (filters, membranes, catalyst substrates, cyclones, centrifuges), refractories (furnace linings, racks, supports, stirrers, ladles, crucibles, kiln furniture), and chemical process equipment (reformers, pumps, valves, piping, tanks, heat exchangers).

103

Bonding of Ceramic Composites for Structural Applications in Fusion Energy Systems--Starfire Systems, Inc., 877 25th Street, Watervliet, NY 12189-1903; (518) 276-2112
Dr. Walter J. Sherwood, Principal Investigator
Dr. Walter J. Sherwood, Business Official
DOE Grant No. DE-FG02-95ER82076
Amount: $74,517

This project will develop techniques for joining silicon carbide fiber/silicon carbide matrix (SiC/SiC) composites for application in fusion energy and other energy production technologies. The techniques will employ silicon carbide precursor polymer. The precursor, hydridopoloycarbosilane (HPCS), pyrolyzes to near stoichimetric, crystalline SiC containing no boron or chlorine. It has been shown to be stable to 1800°C in inert gas and above 1600°C in air. Unlike other preceramic polymers, HPCS produces high char yields (≈80%) and bonds well to all forms of SiC and many types of graphite. In Phase I, three techniques will be utilized to join the composites: (1) joining partially densified composites and finishing the densification (called "composite bonding"), (2) using a slurry of chopped fibers and possibly reactive metal such as vanadium or titanium to join fully densified composites (called "slurry bonding and infiltration"), and (3) using a slurry similar to that above but with chopped carbon fibers and SiC powder partially densified with HPCS and reacted with molten silicon (called "hybrid reaction bonding"). Once fabricated, the joints will be evaluated metallographically and mechanically. This technique can potentially be employed to join dissimilar materials.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful achievement of the Phase I objectives will allow the scaling up of the joining techniques to larger components for fusion systems such as heat exchanger tubes as well as other energy related components including hot gas filter components, gas turbine parts, and high temperature exhaust systems. Some of the techniques may also be applied in ceramic-to-metal joining.

104

Study of a Spherical Tokamak Based Volumetric Neutron Source--TSI Research, Inc., 225 Stevens Avenue, Solana Beach, CA 92075-2059; (619) 793-3567
Dr. Edward T. Cheng, Principal Investigator
Dr. Edward T. Cheng, Business Official
DOE Grant No. DE-FG03-95ER82098
Amount: $75,000

With the worldwide development of fusion power focusing on the design of the International Thermonuclear Experimental Reactor (ITER), developmental strategies for the demonstration fusion power plant (DEMO) are being discussed. A relatively prudent strategy is to construct and operate a small deuterium-tritium fueled volumetric neutron source (VNS) in parallel with ITER. The VNS would provide, during a period less than 20 years, a relatively high capability of 6 MW-a/m^2 in fusion neutron fluence, and 1 MW/m^2 or above in wall loading, over an accessible blanket test area of more than 10 m^2. Such a VNS would complement ITER in testing, developing, and qualifying nuclear technology components and materials and their combinations for DEMO and future commercial power plants. In this research project, small spherical tokamak (ST) reactors will be investigated as the core for the VNS facility. The physics and configuration parameters will be determined for a range of ST designs to identify ST-based VNS design assumptions and critical issues. Solutions will be developed for these critical issues accounting for different candidate fusion blanket concepts. The nuclear performance characteristics of the identified VNS facility incorporating these test blankets will be investigated. Comparison will also be made of nuclear technologies to be tested and demonstrated in the VNS with those anticipated in the full scale DEMO. The Phase I effort will establish the feasibility and the unique features of the ST fusion core for the VNS facility. Results obtained from this study will help to identify a relatively near-term and cost-effective approach for testing nuclear technology in a small but DEMO-like reactor environment.

Anticipated Results/Potential Commercial Applications as described by the awardee: Results obtained from this study will help to identify a relatively near-term and cost effective approach for testing nuclear technology in small but DEMO-like reactor environments. This will complement the mainline efforts of ITER and The International Fusion Materials Irradiation Facility and will enhance their success.

PLASMA DIAGNOSTICS

105

Hardened Tomographic X-Ray Imaging Technology Development for Burning-Plasma Tokamak Fusion Reactors--Boston Physics, 28 Commonwealth Avenue, Boston, MA 02116-3111; (617) 267-7887
Dr. Fredrick H. Seguin, Principal Investigator
Dr. Fredrick H. Seguin, Business Official
DOE Grant No. DE-FG02-95ER81934
Amount: $75,000

X-ray imaging diagnostics, and tomographic imaging systems in particular, are on the official list of required diagnostics for the International Thermonuclear Experimental Reactor (ITER) tokamak. They will provide crucial information about magnetohydrodynamic fluctuations, and sense precursors to disruptive instabilities, that must be monitored and avoided in machine operation. In addition, they will be utilized for determining plasma position and shape, for measuring radiative power during normal tokamak operation, and for other special purposes (such as monitoring impurity transport) during the physics-study phases of burning-plasma tokamak projects such as ITER and the Tokamak Physics Experiment. Conventional techniques applied to x-ray imaging diagnostics on existing tokamaks will not work for burning-plasma tokamaks such as ITER. These techniques involve system components (typically solid-state detectors) that will fail when exposed to the large neutron fluxes that characterize the harsh environments in which they must work. This project will develop a conceptual design for a practical, radiation-hardened, tomographic x-ray imaging system for burning-plasma tokamaks such as ITER. The design will be based on a detector type which is intrinsically immune to radiation damage. In Phase I, a proof-of-principle study will be performed, and a novel type of vacuum photodiode detector, which holds great promise for this application, will be optimized. The optimized detector would form part of a complete system, to be designed in Phase II, which would address issues of diagnostic access, spatial resolution, temporal resolution, and sensitivity.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will produce novel approaches to the design of a crucial type of diagnostic (tomographic x-ray imaging) for burning-plasma tokamaks. A practical design for such an instrument must be developed for the advanced tokamaks now being designed for demonstrating proof-of-principle of fusion power.

106

Accurate Broadband Detectors for Plasma Diagnostics--Boulder Metric, 2440 Kohler Drive, Boulder, CO 80303-5251; (303) 494-9680
Dr. Donald G. McDonald, Principal Investigator
Ms. Alice O. McDonald, Business Official
DOE Grant No. DE-FG03-95ER81935
Amount: $74,955

This project will develop a radiometer specially tailored for plasma diagnostics. This instrument will have greater sensitivity and larger dynamic range, about 80 dB, than broadband room temperature instruments. The sensor is a thermal detector based on high temperature superconductor thin films. It has been experimentally demonstrated that these thermometers have a noise equivalent temperature (NET) as low as 11 nK/√Hz at 87 K with a chopper frequency of 10 Hz or higher. This is a fractional temperature noise of 1.3 x 10^{-10} in a 1 Hz post detection bandwidth. This detector can be continuously calibrated by electrical substitution of power, so it is particularly well suited to high accuracy measurements. Using this high temperature superconductor thin film technology, we can make radiation detectors and radiometers for any part of the electromagnetic spectrum from radio frequency to x-rays, depending on the need. We propose consideration of 3 prototype instruments: An instrument using rectangular waveguide at frequencies up

to 325 GHz, an optical instrument for frequencies of 1 THz and above, and a fiber optic coupled detector for infrared wavelengths shorter than 10 µm. The first generation instrument is expected to have a noise equivalent power (NEP) of approximately 1 x 10^{-11} W/√Hz, and a sub millisecond time constant for the smallest fiber optic coupled device. Larger devices would be slower. Using broadband radiation absorbers, such as tapered terminations for waveguide, and optical traps for shorter wavelengths, absolute accuracies of 1% are expected to be achieved. Second generation instruments would be expected to have improved performance. Our Phase I proposal is to demonstrate our ability to make state-of-the-art superconducting films that we have fabricated.

Anticipated Results/Potential Commercial Applications as described by the awardee: The NEP of this instrument will fall midway between that of the best broadband room temperature instruments, 10^{-9} W/√Hz, and high quality liquid helium instruments, at 10^{-13} W/√Hz. The main market is expected to be in fiber optics engineering for telecommunications, but with other applications to environmental pollution measurements, long term global climate change, fourier transform spectroscopy for material science, and as laboratory calibration instruments.

107

A Reliable Density Profile Diagnostic for Next-Step Fusion Devices--Innovative Research and Technology, 843 Yale Street, Santa Monica, CA 90403-2229; (310) 828-4538
Dr. W. A. Peebles, Principal Investigator
Dr. W. A. Peebles, Business Official
DOE Grant No. DE-FG03-95ER81996
Amount: $74,565

Real-time density profile control has been deemed an essential diagnostic requirement for "next-step" fusion devices epitomized by the International Tokamak Experimental Reactor (ITER) and the Tokamak Physics Experiment (TPX). Historically, interferometry has been adopted for density measurement and density control on fusion plasmas. However, application of interferometry to large, shaped plasmas, such as ITER, is complicated by a variety of factors. The anticipated long pulse operation (≥ 1000 seconds) requires that the chord averaged phase be followed continuously; loss of fringes through vibrations, refraction, etc. would be totally unacceptable. This project will develop and demonstrate a novel density measurement technique ("densitometry") based on the polarization rotation of an electromagnetic wave directed tangentially to the toroidal magnetic field of a tokamak. Densitometry is fully complementary to interferometry and should not be considered as a separate diagnostic system. The primary goal of this project will be to design, fabricate and demonstrate a tangentially viewing, innovative, interferometer/densitometer which combines the attributes of both techniques. The combined system provides redundancy (and therefore improves reliability and availability) and also improves overall accuracy. It is planned to perform measurements in two different spectral regions: the infrared (as a demonstration for fusion devices such as ITER) and the far infrared for immediate application to DIII-D and as a demonstration for future devices, such as TPX. An additional goal for the project is the development of state-of-the-art submillimeter-wave hardware technology required for successful completion of the primary objective. The Phase I project will focus on preliminary design, wavelength choice and accuracy assessment. Phase II will involve fabrication, test and demonstration of the technique on the DIII-D tokamak.

Anticipated Results/Potential Commercial Applications as described by the awardee: A successful completion of the project would find widespread application in the world-wide fusion program. In addition, the resultant hardware development would find application in a variety of research and industrial applications. These include molecular spectroscopy research, radiometry, as well as the ellipsometric measurement of paint thickness on an automobile production line.

108

A Real-Time Multiple Source Video Compression and Storage System--InterScience, Inc., 105 Jordan Road, Troy, NY 12180-8343; (518) 283-7500
Mr. Steven Nordhauser, Principal Investigator
Dr. James T. Woo, Business Official
DOE Grant No. DE-FG02-95ER82106
Amount: $74,070

Over the last decade, the video camera has become a common diagnostic on many magnetic-confinement fusion experiments. Cameras have been utilized for divertor and plasma wall loading studies. To store these data without the losses inherent in videotape, and to access the data in a timely fashion, a real-time digitization, compression, storage, and playback system is planned. Such a system will be developed for multi-channel, flexible, direct-to-disk video recording. In Phase I a single channel of video acquisition, compression, and storage will be demonstrated in hardware. This hardware system will be able to accommodate a variety of algorithms as advances are made in image compression, camera frame rate, and resolution. In the future, multiple channels will be acquired simultaneously, and multiple systems will be networked for real-time data transfer or high-density storage.

Anticipated Results/Potential Commercial Applications as described by the awardee: While this project will result in a "custom" video recorder for the fusion community, such a device is required in many scientific and military research areas. All of the present real-time video recorders have been developed for the large market of multi-media. As a result they have ignored many of the requirements of the smaller market of scientific recorders. There is still a great potential for commercialization within the scientific market, evidenced by the specialized providers of digital data acquisition systems.

109

A 140 Gigahertz Plasma Diagnostic Imaging System--Millitech Corporation, South Deerfield Research Park, P.O. Box 109, South Deerfield, MA 01373-0109; (413) 665-8551
Ms. Ellen L. Moore, Principal Investigator
Mr. Ransom D. Reynolds, Business Official
DOE Grant No. DE-FG02-95ER82031
Amount: $74,978

One of the keys to achieving controlled fusion is to understand the instabilities in plasmas, which are monitored by temperature and density measurements. Some vital information about plasma is obtained only from two-dimensional (2-D) measurements. In particular, 2-D millimeter wave data will form images of mode patterns and give the power spectrum in reflection and the electron temperature fluctuations in emission. This project will complete earlier work on a 140 GHz plasma imaging system which generates 2-D data in the form of a picture, and is therefore referred to as a camera. This camera is both a reflectometer a radiometer. As a reflectometer, it will measure density and phase fluctuations, and radiometric measurements will give the electron temperature fluctuations. Preliminary measurements show that the sensitivity of the radiometric channels should be improved. In Phase I, designs will be studied for increasing the efficiency of the antenna elements and the mixer circuits. Assembly and testing of the density and phase channels will be completed, and these channels will be used to measure beam patterns generated by each of 64 focal plane array elements. In Phase II, an upgraded focal plane array will be built, and any remaining work on the camera will be completed.

Anticipated Results/Potential Commercial Applications as described by the awardee: Two dimensional measurements of plasma electron density, electron temperatures, electron density fluctuations, and the energetic electron distribution might reveal the role of small-scale, fluctuating plasma modes in the interior of a tokamak. The imaging camera would also have applications in contraband detection, all-weather landing systems, intelligence gathering, communications, radios, and remote sensing.

110

Real-Time Neural Network Analysis of Tokamak Current Profiles--Orincon Corporation, 9363 Towne Center Drive, San Diego, CA 92121-3017; (619) 455-5530
Dr. Dariusz Wroblewski, Principal Investigator
Mr. Richard L. Taylor, Business Official
DOE Grant No. DE-FG03-95ER82049
Amount: $74,972

Advanced tokamak concepts critically depend on accessing improved confinement regimes through active control of the current profile. This requires accurate diagnostics of the current profile available from measurements of the magnetic field tilt angle (derived from the Motional Stark Effect (MSE)) and from the geometry of magnetic flux surfaces (determinable from magnetohydrodynamic (MHD) equilibrium analysis but not easily calculated in real time). In Phase I, an artificial neural network will be constructed and trained to map the principal characteristics of the current profile (described by the safety factor, q, a quantity related to the inverse of the magnetic field tilt angle) from external magnetic measurements and MSE measurements. The following parameters of the q profile will be evaluated by the neural network: the central safety factor q; the positions of the $q=1$ and $q=2$ surfaces; and, for reversed q-profiles, the minimum value of q and its location. A set of off-line equilibrium solutions generated by the MHD equilibrium code, spanning the operational space of the DIII-D tokamak, will be used to create the training set of diagnostic data for the neural network. Training will be accomplished by an extended Kalman filter technique that, in Phase II, will provide updates of the mapping between discharges. If the network estimates have a statistically small error, the feasibility of producing control signal outputs will be demonstrated.

Anticipated Results/Potential Commercial Applications as described by the awardee: The feasibility of real-time estimation of the tokamak current profile will permit its active control for improved plasma confinement in advanced tokamaks. Systems for current profile control will become a required feature of future experiments and, eventually, of power reactors, which will be a large commercial market.

TECHNOLOGY AND INSTRUMENTATION FOR HEAVY ION FUSION ACCELERATORS

111

Solid Free-Body Formed Alumina-Tungsten Electrode Insulators for Heavy Ion Fusion Accelerators--Advanced Ceramics Research, Inc., 841 East 47th Street, Tucson, AZ 85713-5009; (602) 792-2616
Dr. Greg Hilmas, Principal Investigator
Mr. Mark Angier, Business Official
DOE Grant No. DE-FG03-95ER82105
Amount: $75,000

A novel solid freeforming process for flexible fabrication of functionally gradient materials has been developed. This versatile process allows for the rapid deposition of viscous ceramic, metallic, or polymer precursor suspensions as bi- or multi-component systems in three dimensions utilizing a computer controlled moving extruder head. This technique has significant advantages over current methods for producing freeformed materials because of its flexibility to almost any material system. The research to be conducted in Phase I will be the development of a material system and fabrication process for producing ceramic-based insulating columns containing embedded metal electrodes formed during the fabrication process. Using the solid free-body forming process combined with functionally gradient materials technology, a prototype aluminum oxide ceramic insulator with tungsten metal electrodes will be produced. The bi-material part fabricated in Phase I will consist of a two inch diameter by two inch high cylinder containing two electrodes and will be able to withstand vacuums to $<10^{-8}$ torr with minimal or no outgassing. The part will demonstrate the ability of this technology to manufacture large scale high voltage accelerating columns for use in heavy ion fusion accelerators.

Anticipated Results/Potential Commercial Applications as described by the awardee: The primary benefit of this project will be development of a fast, inexpensive, and versatile method for preparing freeformed bi-component ceramic insulators. The development and production of this material system and specific application could also lead to notable advances in materials for vacuum feedthroughs, hermetically sealed ceramic-to-metal electrical and optical components, injectors, and numerous other applications.

112

Development of All-Solid-State Drivers for Heavy Ion Fusion Accelerators--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143-4228; (617) 547-1122
Dr. Daniel Birx, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-95ER82108
Amount: $74,956

The next generation of heavy ion fusion accelerators, both linear and recirculating, will require high performance, cost-optimized pulsed power sources with extremely high reliability. Drivers for linear accelerators must produce high fidelity waveshapes at a minimum cost per joule while circular accelerators present additional challenges. Phase I of this project will develop detailed engineering designs for all-solid-state, nonlinear magnetic compressors that will be necessary to meet the requirements of these accelerators. The designs will be based on nonlinear magnetic pulse compression circuits and will be expected to provide high performance power sources with essentially unlimited life. Phase II will focus on a driver for a specific application, fabricate an experimental prototype, and perform accelerated life testing equivalent to the lifetime required of an accelerator driver for inertial fusion energy power generation applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: The application of all-solid-state, magnetically switched driver technology to heavy ion fusion accelerator research will provide greatly enhanced performance and much improved reliability over existing driver designs, and allow for the first time an economically viable accelerator design.

RESEARCH ON THE ELECTRONIC EXCHANGE OF SCIENTIFIC AND TECHNICAL INFORMATION AMONG ORGANIZATIONS

113

A Fuzzy Expert Systems-Based Standard Generalized Markup Language Interface for Access and Collaborative Authoring of Multi-Domain Technical Documents on a Wide Area Network--American Research Corporation of Virginia, P.O. Box 3406, Radford, VA 24143-3406; (703) 731-0655
Mr. John A. Neal, Principal Investigator
Mrs. Anne Churchill, Business Official
DOE Grant No. DE-FG02-95ER81916
Amount: $75,000

There exists a need to implement a collaborative technical document writing and editing interface, based on the Standard Generalized Markup Language (SGML), that can be utilized across a wide area network (WAN). This project will apply computer-based fuzzy expert systems as a domain independent interface capable of providing user access across a WAN. The result will be an expert system control architecture containing fuzzy expert submodules that can provide the required network access and an easy-to-use SGML-based human computer interface. Objectives include the development of algorithms for documentation access across a WAN, the development of expert system control and analysis paradigms, the design of an integrated domain independent SGML collaborative editing environment, and system testing and evaluation. Phase I will demonstrate a proof-of-concept system that utilizes artificial intelligence analysis and control techniques to access technical documents across a WAN. Phase II goals include the development of a fuzzy expert system architecture and graphical user interface that is flexible enough to be used in a variety of remote WAN linkages and domain independent information access applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: Potential commercial applications for this interface can be found in a variety of applications requiring intuitive user access and authoring of multi-domain scientific and technical documents among geographically dispersed sites on a wide area network.

114

A Distributed Multimedia Architecture--Soph-Ware Associates, North 10 Post Street, Suite 448, Spokane, WA 99201-0705; (509) 747-4476
Dr. Ronald C. Turner, Principal Investigator
Mrs. Audrey Wendlandt Turner, Business Official
DOE Grant No. DE-FG03-95ER82071
Amount: $75,000

Distributed multimedia architecture specifies a means to accomplish electronic document interchange among widely dispersed sites and highly disparate platforms. The approach follows the Standard Generalized Markup Language spirit of defining separate layers of abstraction for a document. The most prominent feature of the architecture is a smart entity manager that encompasses all of the services associated with creating, storing, retrieving, editing, transmitting, formatting, and delivering a multimedia document. The manager encapsulates site-specific data, thus promising to provide a low-impact presence of the various DOE educational documents at remote delivery sites. Such external knowledge is concentrated within the manager's highly centralized database, thus ensuring portability for the document. The architecture also specifies tools for human administration of the multimedia manager's services. Phase I will result in a working design for the architecture, proof-of-concept software for the entity manager, and administrative infrastructure among DOE sites and educational organizations. The chief benefit of this architecture is for writers and editors of electronic multimedia documents. By layering and thus "hiding" so much network and systems-specific detail, the architecture leaves the writer free to be creative. The resulting documents themselves, likewise free from such detail, will enjoy a much longer life cycle.

Anticipated Results/Potential Commercial Applications as described by the awardee: The project will investigate the feasibility of the architecture for long-term deployment of standards-defined electronic document initiatives throughout industry and Government. One such instance would be the Technical Resource Directory for the Hanford Knowledge Library. The smart entity manager (a prominent feature of the architecture) will function as a highly portable subsystem which can be imbedded to support the products of any electronic document work group. Those documents may be distributed in any manner and will treat data of any variety.

ELEMENTAL TRITIUM COLLECTION TECHNOLOGY

115

A Novel Tritium Collection Technology Using Fullerene Tritides--Materials and Electrochemical Research Corporation, 7960 South Kolb Road, Tucson, AZ 85706-9237; (602) 574-1980
Dr. X. Lu, Principal Investigator
Dr. R. O. Loutfy, Business Official
DOE Grant No. DE-FG03-95ER82017
Amount: $75,000

A novel technique for glove box tritium collection is proposed using fullerene hydrides. The concept is based on the property of fullerenes to catalytically hydrogenate and dehydrogenate at moderate temperatures with high hydrogen content. By circulating tritium-containing glove box gases through a fullerene-hydride bed, tritium gas would react with fullerene to form tritiated fullerenes. The tritiated fullerenes could be dehydrogenated at reduced pressures to recover tritium gases. The insensitivity of fullerenes to glove box impurity gases such as carbon monoxide, carbon dioxide, and oxygen may simplify the overall tritium collection process. The Phase I project will demonstrate the feasibility of the tritium collection technique, test the properties of tritiated fullerenes, and design and construct a prototype fullerene hydride tritium collection device.

Anticipated Results/Potential Commercial Applications as described by the awardee: A simple, safe, high density, and low cost glove box tritium collection system would find applications for nuclear weapons work as well as for nuclear power generation industry and hydrogen isotope separation plants.

TECHNOLOGY FOR SPACE NUCLEAR PROPULSION AND POWER

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A High Efficiency Dynamic Isotope Power Conversion System--Creare, Inc., P.O. Box 71, Etna Road, Hanover, NH 03755-0071; (603) 643-3800
Mr. Martin A. Shimko, Principal Investigator
Dr. James A. Block, Business Official
DOE Grant No. DE-FG02-95ER81947
Amount: $74,632

This project will produce a prototype dynamic power conversion system suited to long-duration space missions that is based on a unique Stirling engine technology. Twin goals are to minimize both system mass and the quantity of radioisotope fuel per watt of direct current (DC) electrical power delivered. The technical approach is to adapt demonstrated state-of-the-art, long-life spacecraft cryocooler technology to engine/alternator service and to package a fully redundant system around a general purpose heat source (GPHS) module. Preliminary design work on a system suitable for the Pluto Fast Flyby mission indicates the potential for a redundant dynamic system producing 75 W_e from a single 250 W GPHS module with an overall system weight of less than eight kg. Phase I will combine research, analysis, and design efforts to assess critical concept feasibility issues: (1) reliability of hot-end flexures, (2) reciprocating mass requirements for auto-resonant, self-starting operation, and (3) engine/alternator load matching and control under various operating scenarios. Scalability of the concept up to five kW_e output levels will be assessed. Phase II will produce a complete prototype thermal-to-electric power conversion system that can operate from any high to moderate temperature heat supply (solar, liquid propane, natural gas, or furnace exhaust heat sources), including the GPHS module.

Anticipated Results/Potential Commercial Applications as described by the awardee: This reliable, lightweight, and efficient power conversion has numerous terrestrial spinoff applications, such as remote site or emergency backup power generation, domestic cogeneration, or hybrid vehicle powering. Beside efficiency advantages over conventional engine/generator sets, this technology will be much quieter, lending itself to all portable generator applications where noise reduction is a major issue (sail boats, recreation vehicles, bare base military sites, etc.) The engine may also be adapted to drive a refrigerator module in the duplex Stirling mode to provide gas-fired air conditioning, heat pumping, and refrigeration, or wellhead liquefaction of natural gas.

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Bandgap-Engineered Thermophotovoltaic Devices for High Efficiency Radioisotope Power--Edtek, Inc., 7082 South 220th Street, Kent, WA 98032-1910; (206) 395-8084
Dr. Vasan Sundaram, Principal Investigator
Mr. W. E. Horne, Business Official
DOE Grant No. DE-FG03-95ER81957
Amount: $74,918

Radioisotopes have been used as a source of energy for space applications where there is insufficient solar energy to power standard photovoltaic arrays. Thermoelectric devices have proved reliable in past deep space probes; however, their efficiencies are limited to approximately 7%. Future small spacecraft will require more efficient thermal-to-electrical conversion systems. Efficiencies of nearly 20% could be achieved if the bandgap of the photovoltaic converter cells are spectrally optimized for the designated emitter. The application of emitter spectral modification by selective bandpass filtration and/or by a selective rare-earth oxide emitter could further increase the energy conversion efficiency to nearly 25%. It is planned to fabricate thermophotovoltaic (TPV) devices from modified gallium antimonide (GaSb) with a bandgap tailored to the DOE radioisotope general purpose heat source (GPHS) emitter temperature. Models show that the use of these modified converters will provide high TPV efficiency at temperatures of 900° to 1000°C, significantly lower than those required for GaSb or indium gallium arsenide ($In_{0.53}Ga_{0.47}As$). This will relax requirements on cavity performance and provide a greater safety margin on the GPHS iridium-alloy cladding. The Phase I project objectives are: (1) to demonstrate modified GaSb TPV devices by inserting impurities into the GaSb to modify its bandgap, and (2) to develop diffusion, metallization, and photolithographic processes suitable for use with the modified devices.

Anticipated Results/Potential Commercial Applications as described by the awardee: The project will result in sample low-bandgap devices that will demonstrate the required wavelength sensitivity. The resulting improved TPV system efficiency at lower emitter temperature will allow a more reliable and lower-weight, spacecraft power system with an improved safety margin for the GPHS.

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Segmented Thermoelectric Elements for Isotope Power Systems--Hi-Z Technology, Inc., 6373 Nancy Ridge Drive, San Diego, CA 92121-2247; (619) 535-9343
Mr. Norbert B. Elsner, Principal Investigator
Mr. Norbert B. Elsner, Business Official
DOE Grant No. DE-FG03-95ER81983
Amount: $75,000

An innovative thermoelectric power converter is planned that employs two new materials for use at 550° to 1000°C that can be segmented with lower temperature elements. The effort is based on extensive experience in segmenting PbTe and $(Bi,Sb)_2(Se,Te)_3$-based alloys. When combined with the general purpose heat source in a radioisotope power system, the result is a generator with a performance improvement of at least 20%. In Phase I, positive- and negative-leg thermoelectric elements will be demonstrated. An analysis, supporting their incorporation into a space power generator, will be performed.

Anticipated Results/Potential Commercial Applications as described by the awardee: Improved generator efficiency translates to lower overall cost. Greater power per unit mass is important to all missions. Improved static heat-to-electric conversion will benefit commercial users of present-day thermoelectric generators in remote siting applications and in other end uses where durability and long life are requirements. Higher efficiency will also have a payoff in waste heat utilization in many commercial areas.

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Silicides for Space Power and Waste Heat Applications--Hi-Z Technology, Inc., 6373 Nancy Ridge Drive, San Diego, CA 92121-2247; (619) 535-9343
Mr. Norbert B. Elsner, Principal Investigator
Mr. Norbert B. Elsner, Business Official
DOE Grant No. DE-FG03-95ER81984
Amount: $75,000

Silicides are being pursued as thermoelectric materials because of their potential use over a wide range of temperatures, and their potential for being low cost materials. Since the silicides have excellent oxidation resistance it will not be necessary to encapsulate these materials to operate in air. Recent theoretical and experimental studies have indicated how these silicides can be improved. In Phase I, this project will investigate and evaluate new alloy compositions. In addition, theoretical studies will be performed to identify new potential alloy additions. Alloying effects on the electronic properties (metal versus semiconductor, influence on the band gap edges) and alloy stability issues also will be studied. The electronic structure information (width of the band gap, effective masses, and electronic mobility) will be combined with available experimental data to propose a semi-phenomenological model to predict the behavior as a function of materials characteristics.

Anticipated Results/Potential Commercial Applications as described by the awardee: Silicides will be developed that have useful figures-of-merit. These alloys will be made from lowcost elements and will be economical for recovering waste heat from vehicle engines, gas appliances, etc., and generating electrical power via thermoelectric energy conversion.

120

A Modular Isotope Power System with General Purpose Heat Source Thermal Input and a Long-Life Stirling Converter--Stirling Technology Company, 2952 George Washington Way, Richland, WA 99352-1653; (509) 375-4000
Mr. Brad A. Ross, Principal Investigator
Mr. Jeffrey A. Lubeck, Business Official
DOE Grant No. DE-FG03-95ER82079
Amount: $74,974

Radioisotope power systems used for deep space exploration and other missions are currently based on thermoelectric conversion technology with typical efficiencies of 6.5 to 9%. It is projected that an innovative free-piston, linear alternator Stirling converter with the moving components supported by flexural bearings will exceed a 25% efficiency target and meet other radioisotope power systems requirements. The increase in efficiency to 25% will reduce isotope inventory, will dramatically decrease the fuel and life-cycle operation costs, and can potentially lower the mass of the radioisotope power systems. In addition to developing a radioisotope power system that is highly reliable and requires no maintenance for extended periods of time, this system can potentially lower launch hazards and reduce the radiation exposure during ground operations. This project will take an innovative approach by including the use of reduced-mass flexural bearings, the general purpose heat source interface, and the rugged alternator with reduced mass and improved manufacturability. A converter pressure vessel will protect it from harsh environments, and the flexural bearings will isolate the moving components from excessive shock loading. Phase I will advance this technology through the detailed design and endurance testing of the radioisotope piston flexures. Demonstration of endurance is key to establishing the viability of this technology both for space applications as well as for commercial terrestrial applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: Potential commercial terrestrial applications of the power system include weather stations, acoustic beacons, oceanographic and seismic data collection, navigational aids, pipeline control and communication, pipeline cathodic protection, communication translator/repeaters, and wellhead control systems.

MEASUREMENT AND CHARACTERIZATION OF MATERIALS IN CIVILIAN NUCLEAR REACTORS

121

Rotating, In-Plane Magnetization and Magneto-Optic Imaging of Cracks under Coatings on Ferromagnetic Metals--Physical Research, Inc., 25500 Hawthorne Boulevard, Suite 2300, Torrance, CA 90505-6828; (310) 378-0056
Mr. Gerald Fitzpatrick, Principal Investigator
Dr. William C. L. Shih, Business Official
DOE Grant No. DE-FG03-95ER82051
Amount: $75,000

New, more stringent, requirements by the Nuclear Regulatory Commission for the inspection of reactor pressure vessels (RPVs) would benefit from improved nondestructive inspection (NDI) technologies. While magneto-optic/eddy current imaging is a proven NDI technique in nonferromagnetic conductors (e.g., aluminum), it is less successful in imaging ferromagnetic metals, such as a steel RPV wall. This is because the magnetic fields produced by the device are not strong enough to produce observable flux leakage fields from cracks. This project will develop a method to induce a rotating, in-plane, magnetization in ferromagnetic metals, and then employ magneto-optic imaging to form dynamical flux leakage images of cracks. Such images will be superior to static unidirectional flux leakage images produced by weaker retained magnetization. Because of the insensitivity of magneto-optic imaging to liftoff, excellent flaw images in steel should result, even through coatings. In Phase I, basic feasibility will be demonstrated. In Phase II, practical designs for a device capable of performing robotic inspections, both inside and outside a typical RPV, will be perfected. The system will consist of a reduced size, watertight, lightweight magneto-optic imaging system, a "quadrature magnetic yoke" for producing rotating in-plane magnetization, and a special dual-channel power supply for driving the yoke. Images will be captured by a charge-coupled-device camera and transmitted to a point outside the RPV for interpretation.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will result in a remotely-controlled NDI system featuring rotating in-plane magnetization and real-time magneto-optic imaging of cracks and inclusions (under coatings) in ferromagnetic materials.

Because the technology is specifically designed to enhance the NDI of nuclear reactor pressure vessels, it will have many uses in the nuclear power industry, which is facing new, more stringent, inspection requirements. The new technology will also have many applications in the NDI of steel outside the nuclear power industry.

122

A Modular Inspection System for Complete In-Service Examination of a Nuclear Reactor Pressure Vessel, Including the Beltline Region--Quest Integrated, Inc., 21414 68th Avenue South, Kent, WA 98032-2439; (206) 872-9500
Mr. David O. Monserud, Principal Investigator
Ms. Diana J. Suzuki, Business Official
DOE Grant No. DE-FG03-95ER82058
Amount: $74,948

Periodic in-service inspection of nuclear pressure vessel materials is crucial to the assessment of reactor integrity and early detection of service-induced defects. Recent Nuclear Regulatory Commission mandates require more complete examinations than possible with existing technology. Existing interior inspection systems combine ultrasonic testing with cumbersome underwater gantry manipulation. The limitation of existing technology is related to size, access, and positioning repeatability, resulting in an inability to work around internal vessel-specific physical constrictions and obstructions such as spargers, nozzles, jet pumps, and shrouds. In Phase I of this project, locating, maneuvering, and position measuring technologies, recently developed for unrelated applications, will be applied on a chassis only 2 inches high. The platform will initially accommodate ultrasonic and visual sensing and will enable a more complete inspection of orbital welds with more accurate defect location. This inspection system can then be developed for use by operators of boiling water or pressurized water reactor facilities.

Anticipated Results/Potential Commercial Applications as described by the awardee: This technology will enable commercial power plant utilities to meet increasingly demanding inspection requirements. The developed robotic platform and position sensing technology will be applicable to any boiling water or pressurized water reactors from any manufacturer. Reactor service companies have expressed strong interest in this technology. After proving feasibility in Phase I, it is expected that one or another reactor service company will support a prototype demonstration in Phase II, and a partnership will emerge for Phase III commercialization.

CHARACTERIZATION, MONITORING, AND SENSOR TECHNOLOGIES FOR RADIOACTIVE AND HAZARDOUS WASTE

123

A New Method for X-Ray Fluorescence Analysis of Contaminated Materials--NITON Corporation, 74 Loomis Street, Bedford, MA 01730-0368; (617) 275-9275
Dr. Donald Sackett, Principal Investigator
Ms. Ethel Romm, Business Official
DOE Grant No. DE-FG02-95ER82039
Amount: $71,220

A traditional field testing method to determine contaminant levels in materials such as soil, concrete, or paint for contaminating elements involves the use of x-ray fluorescence (XRF). The substantial absorption effects in the material matrix are corrected for by using a complicated fundamental parameters algorithm. This method fails if the sample is obscured by coatings of paint, epoxy, etc. of unknown thickness and composition. A new method is under consideration that makes it possible to use XRF to accurately and quickly determine the absolute concentration of contaminants underneath coatings without knowledge of the composition or thickness of overlying coatings. The technique will allow a portable XRF instrument to be constructed that is capable of fast (< 1 minute) and accurate measurements of low-levels of heavy metal contamination that are obscured by overlying coatings. For example, sensitivities at the five to 10 ppm level are expected for mercury and lead. For uranium, plutonium, and other transuranium elements, sensitivities of one to two μg/cm^2 are expected. By comparison, Nuclear Regulatory Commission-designated safety levels are 10 μg/cm^2 for ^{235}U and 60 μg/cm^2 for ^{238}U. In Phase I, the detection limits will be determined for surface contamination of (1) uranium, thorium, and mercury, (2) typical fission products strontium, cesium, and iodine, and (3) chlorine. The detection limits will also be determined and the absorption-correction algorithm tested for these contaminants when covered by coatings of varying composition and thickness. A high-resolution (200 eV at 20 keV), high count-rate, thermoelectrically-cooled detection system will be developed and used for these measurements.

Anticipated Results/Potential Commercial Applications as described by the awardee: The result of this project will be a portable XRF instrument capable of rapid elemental analysis with better sensitivities than current XRF instrumentation. In addition to being a valuable tool for DOE decommissioning activities, this instrument will be a very competitive addition to the commercial XRF instrumentation market for soil analysis, residential lead-paint analysis, Superfund site analysis, and scrap metals analysis.

IN-SITU TREATMENT OF METAL CONTAMINATED SOILS AND GROUNDWATER

124

Electrokinetically Enhanced Extraction of Radionuclides, Heavy Metals, and Organics from Soil Using Surfactant Micelles--ISOTRON Corporation, 13152 Chef Menteur Highway, New Orleans, LA 70129-1807; (504) 254-4624
Dr. Tapashi Sengupta, Principal Investigator
Mr. Henry L. Lomasney, Business Official
DOE Grant No. DE-FG02-95ER82007
Amount: $74,864

Remediation of soils with low hydraulic permeability, contaminated with complex mixtures of radionuclides/heavy metals and organics, is a complicated task. The complexities arise partly because the contaminants tend to remain sorbed on the soil matrix, and partly because the low hydraulic permeability of these soils thwarts treatment processes based on hydraulic transport. Surfactant aggregates, called micelles, are well known for their ability to dissolve water insoluble organic substances. Electrokinetics, electric field-induced transport phenomena, has the proven ability to overcome transport limitations encountered in the treatment of soils with low hydraulic permeability. In view of this, a process is planned for the decontamination of mixed waste sites, which combines surfactant-based organics solubilization techniques and electrokinetics. The application of surfactant micelles is intended not only for the dissolution of toxic organics from soil, but also to solubilize and deliver certain highly selective metal complexing organic ligands to soil. The delivery of electrically charged micelles and the recovery of micelle-solubilized contaminants and unreacted reagents are expected to be greatly facilitated by the use of electrokinetics. An electrokinetic process is currently being pilot tested for the remediation of uranium-contaminated soil. Phase I will investigate the feasibility of implementing this process scheme to develop a field scale technology. At the same time, it will address the related issues of secondary waste disposal, effects of the treatment process on soil chemical properties, and process scale up.

Anticipated Results/Potential Commercial Applications as described by the awardee: The technology produced by this research will allow in-situ remediation of soils contaminated with complex mixtures of radionuclides/heavy metals and toxic organics, without having to use separate treatment methods for inorganic and organic contaminants. The technology will be effective regardless of soil's hydraulic permeability, and will incorporate a technique for effecting selective metal complexation, the crux of many soil decontamination processes. The technology will provide for an efficient, cheap, and harmless way of treating mixed waste sites.

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Phytoextraction of Heavy Metal Contaminated Vadose Zone Soils--Phytotech, Inc., 1 Deer Park Drive, Suite I, Monmouth Junction, NJ 08852-1920; (908) 438-0900
Dr. Yoram Kapulnik, Principal Investigator
Dr. Burt Ensley, Business Official
DOE Grant No. DE-FG02-95ER82053
Amount: $70,609

Phytoextraction is a technology that uses specially selected metal-accumulating plants to clean up soil contaminated with heavy metals. Initial analysis indicates that phytoextraction provides an attractive and economic alternative to currently practiced soil removal and burial methods. Specially selected metal-accumulating plants can remove solubilized heavy metals from solid substrates to below regulatory standards and allow reclamation and recycling of these metals. However, in most soils heavy metals are complexed, sorbed, or precipitated and are not readily available for plant uptake. Phase I of this project will assess the potential for heavy metal removal from vadose zone soils, using metal-accumulating plants in combination with selected soil amendments that enhance the availability of As, Cd, Cr, Cu, Ni, Pb, and Zn.

Anticipated Results/Potential Commercial Applications as described by the awardee: Commercial application of phytoextraction technology will result in efficient and economical methods for reclamation of contaminated soils. Scale-up and commercialization activities in Federal agency and private sector markets will immediately follow a demonstration of feasibility.

CHEMICAL SEPARATION PROCESSES FOR WASTE TREATMENT

126

Differential Processing to Separate Radionuclide and Volatile Organic Compounds from Soil and Groundwater by Air-Sparged Hydrocyclone Technology--Advanced Processing Technologies, Inc., P.O. Box 58131, Salt Lake City, UT 84158-0131; (801) 581-1792
Dr. Ye Yi, Principal Investigator
Dr. Ye Yi, Business Official
DOE Grant No. DE-FG03-95ER81911
Amount: $75,000

There is a wide variety of radioactive, toxic, and heavy metal contaminants in the groundwaters and soils at DOE facilities. Some of the most common are uranium, technitium, trichloroethylene, and polychlorinate biphenyls. Demand exists for the ability to remove contaminates selectively and efficiently from groundwater and soil, while removing as few non-contaminates as possible. A successful separation process must be capable of removing small amounts of radionuclide particles or other heavy metals from very large quantities of soil or water. It also should be capable of effectively removing minimum quantities of small particles from large quantities of soil with the same fine particle size. In Phase I of this project, the contaminated water (or slurry for the case of solids) will be processed by air-sparged hydrocyclone technology, a new technology that has demonstrated a strong potential for this application. During the process, the volatile organic contaminates (VOC) will be stripped out first. Then, an appropriate flotation reagent will be added, and radionuclide particles will be recovered into a concentrate. The stripped VOC can then be either vented into the air or absorbed by activated carbon. The concentrated radionuclide can be further processed to become a highly pure product, either ready for disposal or for use in other applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: Data have been obtained to show that this technology would be capable of removing both radionuclide and VOC either from soil or groundwater. Once fully developed, the technology can be used at all DOE facilities as well as some EPA superfund sites that have similar contamination problems.

127

A Process to Denitrify Radioactive Waste Streams--Drinkard Metalox, Inc., 2226 North Davidson Street, Charlotte, NC 28205-1830; (704) 332-8173
Dr. Robert Goozner, Principal Investigator
Mr. Fred Gallagher, Business Official
DOE Grant No. DE-FG02-95ER81952
Amount: $75,000

A major goal in the management of radioactive waste streams is to reduce the magnitude of waste to facilitate its disposal. This is especially important in aqueous waste streams where only a small percentage of the waste is radioactive. These aqueous liquids are typically high ionic strength, multi-component solutions of salts dominated by cationic species such as nitrates, nitrites, carbonates, and phosphates. The radioactive species in solution can include plutonium, neptunium, americium, curium, cesium, and strontium. Decontamination procedures frequently consist of using a solvent consisting of dilute nitric acid, and the resulting liquid waste is a dilute solution of such radioactive species. There is a hydrometallurgic technology which has proven highly effective in a number of environmental and ore processing applications. This process can be adapted to the denitrification and concentration of aqueous radioactive waste streams. This application is very similar to the metal recovery processes that were developed for other applications to remove and concentrate metals. The specific Phase I goals are to demonstrate the process on the laboratory bench using representative nitrate doped solutions, determine which denitrification agents have the lowest formation of nitrous oxide, and show that the dentrified liquid is sufficiently free of residual nitrates.

Anticipated Results/Potential Commercial Applications as described by the awardee: The end result of the research will be a commercialized technology to denitrify and concentrate radioactive waste streams. The market for this technology will include such large sites as Hanford, Savannah River, and Oak Ridge, as well as nuclear reactors used for electric power generation and research.

128

A Novel Approach to the Removal of High Concentrations of Nitrate and Nitrite from Aqueous Waste Streams--Lynntech, Inc., 7610 Eastmark Drive, Suite 105, College Station, TX 77840-4024; (409) 693-0017
Dr. King-Tsai Jeng, Principal Investigator
Dr. Oliver J. Murphy, Business Official
DOE Grant No. DE-FG03-95ER82012
Amount: $75,000

The goal of this Phase I project is to demonstrate the feasibility of using a novel approach to the removal and destruction of high concentration, non-radioactive nitrate and nitrite, as well as organics, from radioactive aqueous wastes. Nitrates and nitrites, which constitute the largest fraction of wastes at some DOE sites containing radioactive species, increase volume and cost requirements, increase safety risks, complicate waste processing, and can increase the leaching of other components from waste forms. There is an urgent need to remove them effectively and efficiently. Since nitrates and nitrites are strong oxidants, they can be easily reduced by electrochemical means. The key to this novel approach is that aqueous waste streams containing high concentrations (up to several molar in nitric acid) of nitrate and nitrite will be converted into harmless nitrogen and oxygen without removing the radioactive species from the treating system. In addition, hazardous organics, which pose serious environmental threats and can reduce the effectiveness of some methods for removing metals from waste streams, can be removed simultaneously.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result is the development of a novel process for the treatment of aqueous waste streams containing high concentrations of nitrates and nitrites. Spin-off technology associated with this project can be used in a variety of commercial applications. Potential applications include the mining industry, metal processing, electroplating, the nuclear energy industry, and chemical waste destruction services.

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Ion-Selective Ceramic Membranes for Separation of Radioactive Wastes--Materials and Systems Research, Inc., 62 East Cleveland Avenue, Salt Lake City, UT 84115-5328; (801) 466-1262
Dr. Jan-Fong Jue, Principal Investigator
Dr. Anil V. Virkar, Business Official
DOE Grant No. DE-FG03-95ER82018
Amount: $74,981

This project will develop electrochemical cells for the separation of radioactive waste using highly ion-selective ceramic membranes. Polymeric membranes used in similar applications are neither ion-selective nor stable under irradiation. Recent work has shown that certain ceramic membranes are highly selective; while sodium ions could be easily electrolyzed through the membrane, no aluminum ions could be detected. This project will fabricate these ceramic membranes in the form of thin films over porous supports, as well as in the form of discs. A protective coating will be deposited on these to suppress or eliminate potential corrosion in acidic media. Electrochemical cells will be designed, constructed, and tested. Typical cell operation temperature will be approximately 70°C. Aqueous salt solutions containing nitrates of sodium, cesium, rubidium, and strontium will be electrolyzed through these ceramic membranes. The objective is to demonstrate that only sodium ion can transport through the membranes. In this manner, other impurities can be concentrated in one compartment. The electrochemical performance of the membranes will be evaluated, and the catholyte and anolyte solutions will be chemically analyzed. It is expected that the chemical analysis will confirm the excellent ion-selectivity of these membranes. The membranes will be examined by scanning electron microscopy and x-ray diffraction. At least one cell will be run for a couple of weeks. In Phase I, only nonradioactive impurities will be used. In Phase II, radioactive elements will be incorporated. Also in Phase II, stability to irradiation will be evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated results of the work include ion-selective membranes and electrochemical cells for radioactive nuclear waste cleanup, salt-splitting in paper and pulp industry, and for application in chemical industry for chlor-alkali cells. In addition, these membranes will be ideally suited for application in electrochemical sensors.

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Removal and Concentration of Heavy Metals and Radionuclides from Polluted Groundwater--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025-1516; (415) 328-2228
Dr. Kaaeid Lokhandwala, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-95ER82023
Amount: $75,000

Coupled transport with supported liquid membranes is a method of selectively removing toxic metal ions present at low concentration from contaminated groundwater. The technique concentrates the metal ions 10,000-fold, and the concentrated solution can then be evaporated to a dry solid for safe disposal. The treated water can be safely reinjected into the aquifer. Although the potential of coupled transport for groundwater treatment has been demonstrated in the laboratory, instability of the membranes has hindered further development of the process. Recently, a method of producing stable coupled transport-supported liquid membranes that showed no decrease in membrane performance over a six-month period was demonstrated. This capillary membrane module design is not, however, economically viable for a large-scale industrial process. In this project flat-sheet membranes will be used in a new counter-flow, spiral-wound module. This type of module can be scaled up to the 100 m^2 membrane area scale required for this technology and can be produced at a realistic cost. This counter-flow design also allows the very high removal and the very high separation factors required in a single pass through the membrane module. In Phase I, laboratory-scale modules incorporating a coupled transport carrier agent will be prepared using 12-inch-wide membranes. The performance of the modules will be evaluated with 1 to 10 ppm uranium solutions similar to contaminated groundwater found at the Hanford Nuclear Reservation and elsewhere. In Phase II, the modules will be developed to an industrial scale, and a pilot plant constructed and evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: If successfully developed, the membrane modules will finally allow coupled transport to be used on an industrial scale. Removal of toxic metal ions from contaminated groundwater is one of many applications for this technology. Other applications exist in remediation programs at DOE, in hydrometallurgical extraction of metal ions in the mining industry, and in metal-ion separations throughout U. S. industry.

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An Advanced Nuclear Air Precleaner--Micro Composite Materials Corporation, 4608-D Industry Lane, Durham, NC 27713-5414; (919) 544-1717
Dr. Steve R. Wright, Principal Investigator
Mr. H. Steven Crouch, Business Official
DOE Grant No. DE-FG02-95ER82026
Amount: $75,000

Disposal of nuclear-contaminated high efficiency particulate arrestor (HEPA) air filters has major financial and environmental impacts. The time duration for replacement of these costly HEPA filter elements can be greatly extended if they are combined with novel non-barrier submicron exclusion prefilters, while maintaining traditionally high HEPA filtration and safety standards. This self-cleaning, prefiltering device, which can be designed to have an extended service lifetime measured in years, will collect nuclear particles without prefilter element fouling and subsequent disposal. The devices (1) can operate at >500°C, (2) have a low, constant pressure drop that does not deteriorate over time, (3) are not affected by high particulate loadings or humidity, and (4) can accommodate high gas flow rates. In Phase I regulatory codes and guidelines will be compiled that require modification for DOE testing and Nuclear Regulatory Commission compliance for this new type of prefilter. A computer flow simulation model of the exclusion filter will be adapted to generate a prototype design specific to submicron nuclear air precleaning. A subscale version will be fabricated and minimally tested to determine the feasibility of filtering 0.3 micron particles. In Phase II a full-scale unit will be designed, fabricated, comprehensively tested, and evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: These filters would provide added protection against potential system upsets at nuclear processing facilities, enhance operator safety (reductions in radioactive exposure and material handling), significantly minimize wastes, and, ultimately, decrease the high costs of nuclear air cleaning. Commercial applications include EPA particle emission compliance on high-temperature industrial processes and replacement for filter bag houses, cyclones, and electrostatic precipitators.

132

Destruction of Organic Pollutants in Radioactive Aqueous Waste Streams--Solox, 10635 King William Drive, Dallas, TX 75220-2412; (214) 556-2376
Mr. Bennett C. Howell, III, Principal Investigator
Mr. David L. White, Business Official
DOE Grant No. DE-FG03-95ER82070
Amount: $74,995

This project will demonstrate destruction of organic pollutants in radioactive aqueous waste (mixed) streams with an ultraviolet (UV) oxidation system. The excited state of uranium (VI) will be evaluated as an oxidizing agent or photosensitizer for the destruction of organics. The potential for indirect oxidation of organics by formation of the hydroxyl radical with typical contaminants (specifically nitrates) of mixed streams will be considered. The relationship between oxidation rate and ionic containment concentration will be empirically defined. The reactor will be modified to improve oxidation in radioactive aqueous streams, primarily by modifying the lamp spectral distribution. Toluene and tributylphosphate are the representative organic compounds. Feasibility tests will be conducted in bench scale reactors. Phase I will demonstrate the performance of UV oxidation systems for application to organically contaminated radioactive aqueous waste streams.

Anticipated Results/Potential Commercial Applications as described by the awardee: Destruction of organics would reduce the storage, handling, and disposal requirements for these wastes with the elimination of Resource Conservation and Recovery Act (RCRA) components. Mineralizing organics will simplify processes for separation of other components that are sensitive to the presence of organics.

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Selective Removal and Recovery of Heavy Metals from Contaminated Waters--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033-1916; (303) 940-2301
Dr. Kevin J. Gleason, Principal Investigator
Mr. Michael E. Karpuk, Businessz Official
DOE Grant No. DE-FG03-95ER82089
Amount: $75,000

The contamination of groundwater by heavy metals, radionuclides, and organics is a serious environmental problem. The environmental remediation processes used to clean up contaminated sites generally produce large volumes of water contaminated with low concentrations of metals. The well-established processes used to precipitate metals and reduce them to nonhazardous solids are relatively inexpensive when carried out on concentrated waters. However, these same processes can be prohibitively expensive if applied to large volumes containing dilute metals as well as other pollutants. This project will develop a process for the selective removal and recovery of heavy metals from pump-and-treat or soil washing waters. The process is based on a novel sorbent material that has a high capacity for the heavy metals for interest. A significant benefit of the sorbent is the capability to desorb the heavy metals for recovery and re-use. In Phase I, the sorptive behavior of the material will be evaluated, focusing on the heavy metal removal performance in the presence of other potentially interfering contaminants. During Phase I, a site will be selected for a Phase II test. Phase II, if warranted, will design and develop the hardware to implement this process, and optimize the system for maximum heavy metal removal. In the second year of the Phase II effort, a pilot demonstration of the heavy metal removal system is planned.

Anticipated Results/Potential Commercial Applications as described by the awardee: If this project (Phase I, II, and III) is successful, the result will be a low maintenance, easy to use process for the removal and recovery of heavy metals from contaminated waters. The system could find use in environmental remediation projects at both government and civilian sites. Based on the results of this study, the treatment of other heavy metal contaminated streams may be considered.

COMPUTER STORAGE AND ANALYSIS FOR NONPROLIFERATION DATA COLLECTION

134

Data Fusion for Timely Screening of Treaty Verification Data--AbTech Corporation, 1575 State Farm Boulevard, Suite 1, Charlottesville, VA 22901-8611; (804) 977-0686
Mr. Gerard J. Montgomery, Principal Investigator
Mr. Gerard J. Montgomery, Business Official
DOE Grant No. DE-FG02-95ER81907
Amount: $74,911

This project presents an innovative approach to treaty information screening and assessment that intelligently combines multi-sensor data and situational information using advanced computing technologies. Intelligent processing of diverse types of data and information provides a capability to deal more robustly with a greater number of treaty verification scenarios. This project will develop a sensor information fusion system, Abductive Information Modeling (AIM Fusion), based on a unique abductive reasoning tool, AIM Expert. AIM Expert is ideal for defining and validating synergistic data and information fusion techniques to produce timely decision knowledge. AIM Expert tightly-couples a powerful data modeling technology (AIM), a production rule system, and an intelligent database management system. The result is a software tool that can be used to build a wide range of information assessment and decision aiding systems. AIM Fusion will demonstrate a sensor fusion application that clearly shows integration of diverse sources of treaty ratification information in a timely and meaningful manner. It will integrate sensor data and contextual information using AIM networks, production rules, database management, and conventional software procedures as required for a specific treaty compliance monitor. During Phase I, a well-scoped treaty verification task will be defined, and a prototype capability will be built and demonstrated.

Anticipated Results/Potential Commercial Applications as described by the awardee: In Phase I, a data fusion system for providing assistance with treaty verification will be demonstrated. The demonstration will provide evidence that automatic screening and integration of test ban data is feasible. Phase II will provide a significant capability to automatically screen data and flag events of likely interest for human treaty verification system monitors.

LASER TECHNOLOGY FOR CHEMICAL ANALYSIS FOR NONPROLIFERATION ACTIVITIES

135

A Tunable Solid State Source Driven by a High Performance Diode Pumped Ytterbium Laser--
Aculight Corporation, 40 Lake Bellevue, Suite 100,
Bellevue, WA 98005-2480; (206) 451-9558
Dr. Roy D. Mead, Principal Investigator
Dr. J. J. Ewing, Business Official
DOE Grant No. DE-FG03-95ER81908
Amount: $75,000

Laser sources can remotely sense chemical effluents and atmospheric constituents. Diode pumped (DP) solid state lasers offer great promise for high efficiency and compact size. The commercial reality of DP lasers, with energy and power relevant to remote sensing, is restricted because of the number and cost of diode arrays needed. An alternative to the conventional neodymium (Nd) drive laser, using fewer diode arrays, would aid commercialization. This project will develop a tunable source based on diode pumped ytterbium (Yb) lasers and high efficiency non-linear optical converters. Yb lasers have five times the energy storage compared to Nd, and thus can have considerably more energy output per diode pump array and per dollar of cost for expensive diode arrays. The Phase I effort will experimentally measure the short pulse, Q-switched performance of the most promising diode pumped candidate, Yb doped in strontium fluoroapatite. Measurements of the laser state dynamics lower level depletion, gain, and extraction efficiency will also be made. A simple long pulse chromium: strontuim aluminum fluoride laser will be used to optimally pump the medium, emulating indium gallium arsenide laser arrays. The experimental data will be used to benchmark laser design codes. A design for the Phase II laser will be developed, consistent with delivery of a drive laser for integration into a mobile lidar testbed. A novel optical parametric oscillator (OPO) will be analyzed for implementation in Phase II. The OPO concept offers high conversion efficiency at relaxed peak power conditions.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned effort will develop diode pumped solid state lasers aimed directly at the heart of the pulsed laser market for scientific and certain industrial and medical applications. The DOE, as well as NASA and DOD, will benefit in applications needing compact, efficient, reliable, and robust lasers, based on affordable commercial technology for remote sensing.

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Gallium Phosphide Ultraviolet Diode Arrays--
AstroPower, Inc., Solar Park, Newark, DE 19716-2000; (302) 366-0400
Mr. Paul E. Sims, Principal Investigator
Mr. Thomas J. Stiner, Business Official
DOE Grant No. DE-FG02-95ER81929
Amount: $75,000

A gallium phosphide (GaP)-based, ultraviolet sensitive, positive-negative junction, photodiode detector pixel array is planned. This array will consist of multiple, individually addressable monolithically integrated devices on a semi-insulating GaP isolation layer. Low leakage current and good signal-to-noise ratios will provide detector sensitivity superior to state-of-the-art silicon detectors, and GaP will be more cost effective than silicon carbide or gallium nitride devices. This array will have increased signal-to-noise ratio and better long term stability than existing silicon ultraviolet (UV) detector arrays and will also provide superior performance in high temperature, high radiation, and high intensity environments. Development of this detector array will result in an accurate and stable instrument capable of measuring spectral irradiance and spatial distribution in the 200 to 400 nm UV region. The Phase I project will verify the feasibility of this approach by fabricating and testing prototype UV detector arrays. The critical development tasks are: (1) combining the epitaxial growth of electrically active layers with semi-insulating layers and (2) using planar implantation techniques to define pixel elements that can be addressed by standard photolithographic metallization techniques.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful completion of this project will demonstrate a new class of high sensitivity GaP based UV detector arrays. These arrays will be used in a variety of applications, such as chromatography, UV imaging, medical diagnosis, nondestructive testing, and high energy physics research.

137

Development of Modulator Quality Rubidium Titanyl Arsenate Crystals for Remote Sensing Laser Systems--Crystal Associates, Inc., 15 Industrial Park, Waldwick, NJ 07463-1512; (201) 612-0060
Mr. Richard Stolzenberger, Principal Investigator
Mr. G. M. Loiacono, Business Official
DOE Grant No. DE-FG02-95ER81948
Amount: $74,953

Methods will be developed to improve the properties of rubidium titanyl arsenate as related to the performance of GHz-range electro-optic modulators. The basic properties essential to performance include low dielectric loss tangent, high optical damage threshold, freedom from strain or voltage induced birefringence, high electro-optic coefficients, low optical insertion loss, and good optical homogeneity. Three specific problem areas have been identified in the growth and fabrication of modulator quality rubidium titanyl arsenate: (1) birefringence inhomogeneity, (2) inconsistent crystal impedances from growth run to growth run, and (3) a general lack within the crystal growth industry of the manufacturing expertise required to fabricate modulator crystals to the critical orientation, dimensional, and surface finish tolerances demanded by high frequency modulator applications. Phase I will address the first two problems by thorough characterization of present crystal growth, followed by modifications of the synthesis, growth, and processing steps. The third problem will be solved by using facilities and techniques already in place to develop processes which will insure that orientation, dimensional tolerances, and finishes on rubidium titanyl arsenate samples will be adequate for the operation of modulators in the GHz range. Phase I will result in the identification of preliminary processing solutions that will lead in Phase II to a supply of large, modulator-quality rubidium titanyl arsenate electro-optic material and improved modulation and switching components.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that Phase II will result in an improved source of visible through near infrared electro-optic material as well as improved modulation and switching components for laser systems in a large variety of commercial applications. These applications include pollution monitoring, medical diagnostics and therapeutics, communications, spectroscopy, laser stabilization, and graphic arts.

138

Rugged, Tunable Infrared Laser Sources--Deacon Research, 2440 Embarcadero Way, Palo Alto, CA 94303-3313; (415) 493-6100
Dr. Douglas Bramford, Principal Investigator
Dr. Olive Lee, Business Official
DOE Grant No. DE-FG03-95ER81950
Amount: $75,000

Tunable infrared lasers are an essential component of the DOE nuclear nonproliferation program because of their ability to remotely detect effluents resulting from the processing of nuclear material. The tunable infrared lasers available today are tabletop laboratory devices not easily adaptable to deployment in an airplane (or in an inspector's briefcase). This project will develop a compact, tunable infrared laser source based on diode laser pumping of a new nonlinear optical material, periodically poled lithium niobate (PPLN). The pump laser and nonlinear crystal can be integrated into a small package with no mechanical tuning elements. By incorporating a novel arrangement of PPLN, a device can be produced with the required spectral properties (narrow bandwidth and wide tuning range) for the remote sensing application. In Phase I, the project will build devices based on this novel arrangement, measure their spectral properties, and measure their nonlinear conversion efficiencies. Using these results, the performance characteristics to be expected from a prototype device to be constructed in Phase II will be calculated. The result will be a narrowband, broadly tunable, frequency agile infrared source useful for nonproliferation in a variety of deployment schemes.

Anticipated Results/Potential Commercial Applications as described by the awardee: The project will produce a compact, all solid state tunable infrared source with the spectral characteristics required by sophisticated remote sensing schemes in the DOE nonproliferation program. The laser source will form the cornerstone of a trace gas sensor with a wide range of applications in environmental monitoring, manufacturing process control, medical diagnostics, and analytical chemistry.

139

A Mid-Infrared Laser for Remote Sensing of Chemicals--INRAD, Inc., 181 Legrand Avenue, Northvale, NJ 07647-2498; (201) 767-1910
Dr. Sergei Govorkov, Principal Investigator
Ms. Maria Murray, Business Official
DOE Grant No. DE-FG02-95ER81998
Amount: $74,994

Many environmentally sensitive chemicals, including chemical warfare agents, have their signature absorption lines in the mid-infrared spectral region. A differential absorption (DIAL) light detection and ranging system, if it were continuously tunable in the "fingerprint" infrared wavelength region, would offer the essentials for an accurate, real-time, chemical monitor for a wide variety of gases. This project will develop an all solid state optical parametric oscillator (OPO)-based laser transmitter for a DIAL system. The approach in Phase I will be to design and build a zinc germanium phosphide based OPO. This will be pumped by a Q-switched, flashlamp-pumped erbium-doped yttrium scandium gadolinium garnet laser. The performance of the system will be evaluated with respect to conversion efficiency, tuning range, and emission linewidth. Based on the data from this system, a conceptual design for an OPO-based DIAL system will be developed.

Anticipated Results/Potential Commercial Applications as described by the awardee: A tunable mid-infrared laser source can be used for remote sensing of stack gases, greenhouse gases, chemical warfare agents, and precursors for illegal drug manufacture. This technology is also suitable for defense applications such as ranging, target designation, and countermeasures.

140

Development of Laser Materials and Rugged Coatings as Components for Tunable Ultraviolet Laser Systems--Lightning Optical Corporation, 431 East Spruce Street, Tarpon Springs, FL 34689-4015; (813) 938-0092
Dr. Arlete Cassanho, Principal Investigator
Mr. Wayne Ignatuk, Business Official
DOE Grant No. DE-FG02-95ER82010
Amount: $71,476

A new laser crystal, Cr^{3+}:$LiSrGaF_6$ (chromium: lithium strontium gallium fluoride), which is potentially superior to Cr^{3+}:$LiSrAlF_6$ (the aluminum analog), will be evaluated for use in tunable laser systems which can operate from approximately 250 to 400 nm. Cr^{3+}:$LiSrAlF_6$ is currently the only crystal that can challenge titanium: sapphire as a broadly tunable, near-infrared laser source. The $LiSrAlF_6$ materials and their isomorphs have an advantage in their potential use in rugged and compact, all-solid-state lasers, since they can be efficiently pumped by diode lasers. However, it is not clear that the state-of-the-art diode pumped Cr^{3+}:$LiSrAlF_6$ laser is the preferred source. Negligible passive loss, coupled to its potentially superior thermo-mechanical and thermo-optical properties, make Cr^{3+}:$LiSrGaF_6$ a worthwhile material to investigate. Cr^{3+}:$LiSrGaF_6$ will initially be characterized using samples already available. This crystal can be grown with practically zero passive loss and in a large boule size when a novel synthesis procedure is used. This same synthesis procedure will be used for Cr^{3+}:$LiSrAlF_6$ to reduce its passive losses to the same level as those measured for Cr^{3+}:$LiSrGaF_6$ crystals. In Phase I, direct comparison of Cr^{3+}:$LiSrAlF_6$ and Cr^{3+}:$LiSrGaF_6$ will be completed in order to determine which material is more robust and better suited for the application. Phase I will also develop a second critical component, antireflective coatings, which are capable of withstanding the rigorous temperature cycling required for tunability and frequency conversion, while maintaining a high damage threshold.

Anticipated Results/Potential Commercial Applications as described by the awardee: New material and coating technologies will be developed which could be utilized in frequency-agile laser systems. Applications range from remote sensing of atmospheric constituents, such as ozone, to studies of various chemical processes which occur in the ultraviolet region of the spectrum.

IMPROVED SENSOR TECHNOLOGY FOR NATIONAL SECURITY AND NONPROLIFERATION OF WEAPONS

141

Resonant Electromagnetic Detection and Mapping of Deeply Buried Cable Networks--Dynamics Technology, Inc., 21311 Hawthorne Boulevard, Suite 300, Torrance, CA 90503-5610; (310) 543-5433
Dr. G. Minot Clements, Principal Investigator
Mr. Dana Eurich, Business Official
DOE Grant No. DE-FG03-95ER81955
Amount: $74,991

A common feature of underground facilities is power, communication, and other cables leading to, and networked throughout, the facility. Passive detection of emission from operating power lines has been demonstrated in previous research. However, detection of deeply buried non-operating cables requires active electromagnetic (EM) illumination and detection of the scattered field. Because of the importance of cable junctions for mapping and interpreting network layouts, it is also desirable to locate these strategic points remotely. This project will develop an active electromagnetic sensor system for detection and mapping of deeply buried cable networks. This system will be built on demonstrated theoretical results and upon recent advances in sensor hardware and signal processing. These techniques will be extended to achieve airborne detection capability and also assess potential detection of cable junctions. In Phase I, feasibility will be demonstrated by: (1) refining the theoretical formalism to calculate cable response in a multilayered medium and determine the required source/receiver characteristics for a practical sensor system, (2) developing preliminary signal processing algorithms, and (3) performing benchmark ground-based field measurements with an existing active EM system. In Phase II, an airborne prototype will be developed, using an existing system developed for other applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: This effort will first provide an identified high priority capability to support U.S. counterproliferation efforts aimed at detecting and characterizing deeply buried underground facilities. The planned sensor system capability will also extend the existing commercial arsenal of geophysical survey tools to support both Federal and commercial environmental site characterization and remediation programs.

142

A Superconducting Gravity Gradiometer for Detection of Underground Targets--GWR Instruments, Inc., 10623 Roselle Street, San Diego, CA 92121-1506; (619) 452-7655
Dr. Richard J. Warburton, Principal Investigator
Dr. Richard J. Warburton, Business Official
DOE Grant No. DE-FG03-95ER81979
Amount: $74,915

Remote detection of underground targets, such as tunnels, bunkers, abandoned mines, and underground waste dumps is of great importance both to the military and to commercial interests. Along with other geophysical techniques, gravity should be included in an integrated package for target detection. Unfortunately, microgravity surveys are expensive, because making precise gravity meter readings is time consuming, and a precise elevation survey is also needed for interpretation of data. In contrast, vertical gravity gradient surveys do not require precise elevations and provide sharper definition of shallow target anomalies. To take full advantage of a gradiometer, one must be able to take readings quickly so that sufficient surface data can be taken to spatially resolve and separate shallow features from deeper targets of interest. This project will start development of a new portable vertical gravity gradiometer which will be sensitive enough to detect small tunnels and bunkers at depths up to 20 meters and will allow a reading time of about a minute. In Phase I, a single axis stationary gravity gradiometer will be constructed by differencing signals from two superconducting gravity sensors built into a common cryostat. The gradiometer noise level will be measured, alternative methods to further decrease instrumental noise investigated, and the rapid and highly sensitive measurements demonstrated.

Anticipated Results/Potential Commercial Applications as described by the awardee: A portable gravity gradiometer would have numerous military, engineering, and environmental applications. These include: detection of tunnels, bunkers, abandoned mine workings, and sink holes (solution features), and the monitoring of perimeters of high security areas or of sites of underground waste contamination.

143

Chemical Microsensor Arrays as Integrated Chip Compatible Devices for Chemical Weapons Nonproliferation Inspection--Microsensor Systems, Inc., 62 Corporate Court, Bowling Green, KY 42103-7023; (502) 745-0099
Dr. Hank Wohltjen, Principal Investigator
Dr. Hank Wohltjen, Business Official
DOE Grant No. DE-FG02-95ER82029
Amount: $74,953

Solid-state chemical microsensors, such as Surface Acoustic Wave (SAW) devices and chemiresistors, have inherent advantages of small size, low cost, reliability, and high performance. They are also uniquely compatible with existing integrated chip (IC) standards and can be controlled remotely by existing microprocessors. Chemical microsensors thus appear ideal candidates for development as small, cost effective, rugged sensors for chemical weapon inspection. However, the principal limitation of all solid-state chemical microsensors for the detection and identification of gases and volatile organics is their relatively poor selectivity. One approach to improving selectivity has been to use arrays of devices in combination with pattern recognition algorithms in order to correlate the signature of the responding sensors with the chemical composition of the vapor. The success of this approach depends on the ability of each sensor to provide an independent, orthogonal response to a vapor challenge. Unfortunately, the various chemically selective coatings available for SAW sensors do not differ sufficiently in their vapor response to be effective for more than simple mixtures. Thus, this project will develop a new approach for achieving chemical selectivity with microsensors: a sensor array that contains different types of microsensors as well as SAW sensors with different coatings. Phase I will investigate a microsensor array that contains SAW, chemiresistor, and metal oxide semiconductor devices to provide an array of data containing three different kinds of chemical information: vapor solubility properties, electronegativity, and total organic content. A data analysis algorithm will be developed to determine the degree to which each sensor contributes to the vapor analysis. Selectivity will be optimized to determine the best mix of sensors in an array that is small and IC compatible.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that chemical microsensor arrays developed in this project will have high sensitivity and selectivity for a wide range of hazardous vapors beyond those related to chemical nonproliferation. Thus it is anticipated that the sensor array will rapidly find a commercial application in a variety of industrial and environmental monitoring areas, including industrial process control.

144

Hand Recognition for Access Control--
Reinholdtsen Measurement Systems, 3767 Bay Road, Menlo Park, CA 94025-1917; (415) 327-9622
Dr. Paul Reinoldtsen, Principal Investigator
Dr. Paul Reinoldtsen, Business Official
DOE Grant No. DE-FG03-95ER82063
Amount: $75,000

This project develops a system for access control based on the that identification of human hands. The system constructs a detailed three-dimensional, fully articulated computer model of the human hand from digitized images. The model captures the overall structure of the hand and give estimates of musculoskeletal parameters such as bone lengths, joint articulation angles, and skin contours. The system also accounts for uncertainty in imaging parameters and hand location and orientation. Although it is a complex estimation problem, recent advances in multisensor fusion make it feasible to determine hand parameters from imagery. Phase I will design a hand geometry identification system using recently developed multisensor fusion techniques. The efficacy of this approach will be demonstrated with a prototype system.

Anticipated Results/Potential Commercial Applications as described by the awardee: A system based on this approach is expected to have a significant competitive advantage over existing commercial biometric verification systems. This approach will provide for ease of use, low error rates, and robustness against fraud.

ENVIRONMENTAL TECHNOLOGY FOR NATURAL GAS, OIL, AND COAL

145

Improved Sensitivity for Environmental Monitors through Innovative Application of Wavelets--ADA Technologies, Inc., 304 Inverness Way South, Suite 110, Englewood, CO 80112-5828; (303) 792-5615
Mr. Thomas G. Carter, Principal Investigator
Dr. Michael D. Durham, Business Official
DOE Grant No. DE-FG03-95ER81909
Amount: $74,731

Many state-of-the-art environmental instruments, based on multi-component analytical techniques, produce complicated signals requiring mathematical analysis to find unique signatures for each compound. This project will apply wavelet-based algorithms to provide a cost-effective means to increase the sensitivity and decrease the impact of interference and noise for these environmental sensors. Wavelet theory is a new mathematical formulation that has already provided dramatic performance improvements in other areas of signal and data processing. The technical objective of Phase I is to demonstrate that wavelet-based signal and data processing algorithms will significantly advance the state of the art for precision and accuracy in environmental emission monitors. This will be done by developing wavelet-based signal processing algorithms and then exercising these algorithms against data from operational environmental monitors. Current state-of-the-art signal processing techniques will also be exercised against the same data sets. Results will be compared to those for wavelet-based algorithms in order to demonstrate the performance improvements. Detection limits will be used as the principal figure of merit in these evaluations. The development of signal processing techniques based on wavelets will provide greater near-term performance improvements than can be achieved through hardware research and development.

Anticipated Results/Potential Commercial Applications as described by the awardee: The wavelet-based signal processing approach described in this proposal will result in a new method for improving the sensitivity of environmental monitors, and thus, will have tremendous potential for application to existing and future environmental monitors. Additionally these techniques can be easily adapted for use in biomedical, food and drug quality assurance, and quality control sensors and monitors. The data processing required for remote sensing, military surveillance and tactical sensors, and others are prime candidates for application of new signal processing techniques based on wavelets.

146

A Modified Natural Clay Sorbent for Control of Mercury from Coal Fired Combustors--Energy and Environmental Research Corporation, 18 Mason Street, Irvine, CA 92718-2706; (714) 859-8851
Mr. Jerald A. Cole, Principal Investigator
Dr. Randall Seeker, Business Official
DOE Grant No. DE-FG03-95ER81963
Amount: $74,912

Under Title III of the Clean Air Act Amendments of 1990 the Environmental Protection Agency is required to set standards for allowable emissions of hazardous air pollutants, or "air toxics". Among the metals listed in the act, mercury in electric utilities is identified specifically for study. This project is concerned with the development of a sorbent for control of mercury that promises to have significantly greater cost effectiveness, with comparable or greater removal efficiencies, than the existing state-of-the-art technology: activated carbon absorption. Carbon absorption systems are costly, mainly as a result of the activated carbon costs. Natural clay sorbents have been shown capable of absorbing mercury with a capacity near that of commercial activated carbon. Past work in the field of catalysis showed that the physical structure, and hence specific activity, of a wide variety of natural clays can be modified to enhance specific properties such as absorption of gaseous species. This suggests the potential to modify naturally occurring clays to produce low-cost materials with significantly greater capacity for mercury absorption. During the Phase I study, sorbents developed in laboratory studies will be tested under simulated coal combustion conditions for their capacity to absorb mercury in the presence of potential interferents such as sulfur dioxide, fly ash, and char. The conditions for optimal mercury capture will be evaluated and estimates of the process feasibility assessed.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will lead directly to two commercial processes if shown successful. The first will be a commercial process for preparation of modified natural clay sorbents for use in the control of mercury, and possibly selenium, from combustion systems such as coal-fired power plants. The second process will be the sorbent injection process itself. Both of these technologies will be marketed aggressively to the coal combustion sector as regulations on emissions of toxic metals come into force.

147

A Novel High Efficiency Fine Particulate and Mercury Control Concept--Environmental Elements Corporation, 3700 Koppers Street, Baltimore, MD 21203; (410) 368-7239
Dr. Dennis J. Helfritch, Principal Investigator
Dr. Paul L. Feldman, Business Official
DOE Grant No. DE-FG02-95ER81968
Amount: $74,929

This project will test a novel agglomerator for the growth of fine particulates for subsequent removal by a conventional electrostatic precipitator or fabric filter. The concept to be tested uses a circulating bed of recycled particles to act as agglomerating sites for the fines. Activated carbon may be injected into the agglomerator to allow for combined high-efficiency fine particulate and mercury capture. Collection efficiencies in excess of 99.95% are anticipated for the respirable range of particulates, and mercury control efficiencies will be in the 90% range. Phase I will include the planning and execution of the test program using an existing circulating bed pilot system. The importance of system variables such as residence times, temperature, and humidity on agglomeration will be determined. The need for cohesivity promoters will also be evaluated. Finally, the ability of the systems to remove mercury will be assessed.

Anticipated Results/Potential Commercial Applications as described by the awardee: There is a growing need for effective techniques for dealing with submicron particulate emissions. Conventional collectors are impractical for ultra-high efficiency application. Agglomeration before the conventional collector is a promising approach. Successful development of this concept will find application wherever fine particulate control is needed. The mercury control aspect will be more important with coal-fired boilers and waste incinerators.

148

An Economic Sorbent for the Removal of Mercury, Chlorine, and Hydrogen Chloride from Coal Combustion Flue Gases--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033-1916; (303) 940-2301
Dr. Ravi Mariwala, Principal Investigator
Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-95ER82091
Amount: $75,000

Emission of mercury, chlorine, and hydrogen chloride from coal combustion flue gas is a widely recognized environmental problem. Coal fired power plants currently contribute up to 19% of the anthropogenic mercury emission in the U.S. The toxic effects of mercury and other compounds and the anticipated stringent requirements to lower their emission levels have prompted the development of efficient emission control technology. The Clean Air Act amendments of 1990 require the use of maximum available technology to control the mercury emissions. At present, wet scrubbing and sorbent injection are used to remove the toxic gases from coal combustion flue gas. The sorbent injection process for mercury removal is inefficient because the sorbent used (activated carbon) has low mercury adsorption capacity. Therefore, a large volume of activated carbon is required to treat the mercury-containing flue gas. The mercury that is adsorbed on the large volume of spent carbon is difficult to recover because it is present in small concentrations. Hence, it is expensive to regenerate or dispose of the large volume of spent activated carbon. The commercial sorbents that are specifically available for mercury removal are expensive, because of the additional processing steps required to treat them for mercury removal. A low cost route to a carbon-based sorbent has been identified that should have a high capacity for mercury and also for other air toxics, including chlorine and hydrogen chloride. In Phase I, the new sorbent will be prepared and tested, including measurement of the breakthrough curves with mercury, chlorine, and hydrogen chloride. Initial estimates indicate that the cost of the sorbent should be competitive with that of activated carbon.

Anticipated Results/Potential Commercial Applications as described by the awardee: If successful, the sorbent developed in Phase I will have superior capacity for mercury adsorption, and similar or superior properties for chlorine and hydrogen chloride adsorption compared to activated carbon. The cost of the sorbent will be similar to the cost of activated carbon. Other potential applications of the sorbent include removal of mercury from liquefied natural gas and from hydrogen streams in chloro-alkali plants.

ADVANCED RECOVERY OF OIL

149

Novel Polymer Surfactants for Enhanced Oil Recovery--EIC Laboratories, Inc., 111 Downey Street, Norwood, MA 02062-2668; (617) 769-9450
Dr. Timothy L. Rose, Principal Investigator
Dr. A. C. Makrides, Business Official
DOE Grant No. DE-FG02-95ER81958
Amount: $75,000

Cost-effective advances in the technology of micellar-polymer flooding can lead to an immense increase in enhanced oil recovery (EOR) by this method. New surfactants are required for use over a greater range of reservoir conditions, in particular, those with high brine concentration, elevated temperatures, and carbonate soils. The planned research addresses these challenges by developing a new class of polymeric surfactants. The structure of the surfactant will promote formation of microemulsions at high salinities, reduce sorption on soil surface, and inhibit degradation at higher temperature. Cost reductions are also expected because the low value of the critical micelle concentration requires less surfactant, and the viscosity of the polymer surfactant solution will reduce the need for additional polymers in the surfactant slug. Further cost reductions may be possible if the polymeric surfactant could be recycled. Research in Phase I will synthesize the polymer surfactants from low-cost, readily available, starting materials. The phase behavior, viscosity, and sorption of the surfactants in oil/water mixtures will be measured over a range of salinities and temperatures.

Anticipated Results/Potential Commercial Applications as described by the awardee: The new class of polymer surfactants will operate under harsh conditions to expand the number of reservoirs that can be treated by chemical EOR. Up to 10 billion additional barrels of oil could be recovered using advanced surfactant technology. Other potential applications for the new class of surfactants include subsurface remediation of groundwater polluted with organic contaminants and a host of applications where water soluble emulsifying agents are required.

150

An Infrared Mineralogical and Oil Log--Standard Geological Services, Inc., 6920 Jordan Road, Suite M, Englewood, CO 80112-4248; (303) 680-4816
Dr. Louis H. Taylor, Principal Investigator
Dr. Louis H. Taylor, Business Official
DOE Grant No. DE-FG03-95ER82075
Amount: $74,831

Independent, small or medium-sized oil producers cannot make mineralogical analyses of reservoir rocks and oil field materials a routine part of their operating program because of cost and time factors. As a result, reservoirs and wells may be damaged during drilling or during oil production, leading to a reduction or even elimination of oil production. Also, oil producers lack a consistently reliable, safe technique for detecting oil-in-place within rock samples from a reservoir. Short wave infrared reflectance spectroscopy can provide real-time mineralogical identification and detection of oil-in-place through analysis of reservoir rocks. The analysis is safe, rapid, low-cost, and can be conducted at a wellsite. Resulting analytical data can be used to construct a mineralogical and oil log that will allow operators to quickly and cost effectively determine the possibility of damage during completion of a well. Short wave infrared reflectance spectroscopic analytical data can also be used to identify production damage caused by mineral precipitation. The phase I research will analyze borehole samples with a portable short wave infrared spectrometer. The resulting mineralogical and hydrocarbon data will form the basis of a new logging technique that results in a digital log, prepared at the wellsite, in real-time. The resulting data will also be compared with similar data from analytical techniques confined to the laboratory.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned research will produce a safe, broadly applicable, rapidly applied technique that will provide real-time data about the mineralogy and presence of oil-in-place within reservoirs. The technique will be less expensive than traditional analyses used to provide these data. The technique will be used to construct a well log that can be used by an operator to make proper and timely decisions about well treatments, completion, and production testing.

NATURAL GAS SUPPLY

151

A Membrane-Based Process for the Removal of Nitrogen from Natural Gas--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Dr. David K. Lyon, Principal Investigator
Mr. Kelly L. Smith, Business Official
DOE Grant No. DE-FG03-95ER81931
Amount: $74,912

About 23 trillion cubic feet of U.S. natural gas reserves contain nitrogen (N_2) concentrations too high to meet current pipeline specifications. No current technology can economically remove N_2 from most N_2-containing natural gas. The objective of this project is to develop an economical, membrane-based N_2-removal process. Although others have recognized potential advantages of membrane-based systems, no membranes with sufficient selectivity toward nitrogen over methane (and other hydrocarbons) have been identified. The goal of this project is to develop such an N_2-selective membrane that has a high selectivity toward nitrogen over methane and a high pressure-normalized nitrogen flux. Based on the membrane performance targets for this project, the predicted cost of N_2-removal costs will be \$0.10 to 0.20 per 1000 standard cubic feet (MSCF) of gas processed, much lower than current processes (e.g., \$0.50 to 1.00/MSCF for cryogenic processes). Phase I is aimed at development and testing of a novel N_2-removal membrane in dense flat-sheet and composite hollow-fiber form. Phase II would be aimed at further improving membrane performance and modularization of the membrane for testing under simulated process conditions. Scale-up and commercialization would occur in Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: This technology promises to lead to N_2-removal costs well below those of any current technology--particularly at small scale, where much of the N_2-containing gas cannot be economically produced. Thus, this technology should allow many of the N_2-containing natural gas reserves to be tapped economically.

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Liquid Absorbents for Nitrogen Removal from Natural Gas--Bend Research, Inc., 64550 Research Road, Bend, OR 97701-8599; (503) 382-4100
Mr. David K. Lyon, Principal Investigator
Mr. Kelly L. Smith, Business Official
DOE Grant No. DE-FG03-95ER81932
Amount: \$74,925

Natural gas provides more than one-fifth of all primary energy consumed in the U.S. However, about 23 trillion cubic feet of this gas contains nitrogen (N_2) concentrations too high to meet pipeline specifications. No technology currently exists that can remove this N_2 economically. The best available technology for reducing N_2 concentration, cryogenic N_2-rejection units, is suitable for only large-scale use, is complicated, and has high capital and energy costs. The goal of this project is to develop a new class of regenerable, N_2-selective liquid absorbents for use in an economical N_2-removal process similar to that used for amine-based gas sweetening. In Phase I, feasibility will be demonstrated by combining the advantages (i.e., N_2-binding performance, water solubility, stability, and other favorable properties) of an existing class of N_2 absorbents with the improved availability and lower synthesis costs of this new class of complexes. Phase II work would be focused on improving the N_2-binding capacity of the absorbent and evaluating other absorbent properties such as stability and reaction kinetics, with the goal of attaining performance that would result in processing costs of \$0.30 per thousand standard cubic feet. The Phase II project would culminate in a bench-scale test of the new liquid absorbent.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of the envisioned multi-phase project will enable use of the large quantities of natural gas currently rendered unusable by high nitrogen content. This will help keep energy costs low and decrease U.S. dependance on foreign energy sources. In addition, the approach used to develop N_2-selective absorbents can be used for many other industrial separations such as olefin/paraffin and olefin/olefin separations.

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Electrochemical Activation of Natural Gas Constituents to Alcohols Using Bimetallic Anode Electrocatalysts--Eltron Research, Inc., 2830 Wilderness Place, #E, Boulder, CO 80301-5455; (303) 440-8008
Dr. James H. White, Principal Investigator
Ms. Eileen E. Sammels, Business Official
DOE Grant No. DE-FG03-95ER81961
Amount: \$74,995

This project addresses the direct anodic electrochemical activation of alkanes from natural gas sources using novel electrocatalysts. Incorporation of these anode electrocatalysts onto a polymer membrane will allow for the separation of oxygenates from relatively nonpolar alkanes. Anode electrocatalysts will function by virtue of carbon-hydrogen bond activation and interaction of alkyl fragments with water as a nucleophile. This approach allows for continuous adjustment of anode electrocatalyst potential for control of the surface species oxidation rate. The strategy is anticipated to lower the affinity of the surface of the anode electrocatalysts for oxygen containing species destructive towards chemisorbed alcohols or alkoxy fragments. Additionally, the approach will allow for improved anode elctrocatalyst activation through decreased affinity for large organics and a lower tendency for polymeric film formation. In Phase I, anode electrocatalysts will be initially evaluated, the permeability of polymer membranes to products determined, and the performance of polymer electrolyte supported electrocatalysts evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of this project will lead to the determination of anode electrocatalysts and experimental conditions conducive towards the selective conversion of natural gas-derived alkanes to oxygenates and their separation from the product stream.

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An Innovative Membrane and Process for Removal and Recovery of Natural Gas Liquids--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025-1516; (415) 328-2228
Dr. K. A. Lokhandwala, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-95ER82022
Amount: $75,000

Natural gas liquids (NGL) are removed from natural gas to reduce the dew point and Btu value to pipeline specifications and to recover the NGL for use as a chemical feedstock. To meet increased demand for both natural gas and NGL, new technologies are needed for this separation, particularly for smaller streams (< 25 MMscfd). Calculations show that a membrane-based process could be economically competitive if membranes with sufficiently high selectivity for higher hydrocarbons over methane and high flux were developed. Recently, a super-glassy polymer, poly(trimethylsilyl propyne) [PTMSP] was found that combines these properties. The objective of this Phase I project is to demonstrate that PTMSP membranes are highly selective for propane and higher hydrocarbons over methane under a wide range of feed conditions, and that the membrane can be incorporated into a spiral-wound module that retains this high performance, is pressure-stable at pipeline pressures, and is stable under continuous operation. In Phase II, the modules will be scaled up for operation in a test rig first in the laboratory and then in the field.

Anticipated Results/Potential Commercial Applications as described by the awardee: Economic calculations show that a membrane process for NGL removal is potentially less expensive than conventional refrigeration or cryogenic processes, and particularly suitable for natural gas streams available at lower flow rates.

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Pulsed Flow Adsorption Columns for Multi-Component Gas Separation--Northwest Fuel Development, Inc., 4064 Orchard Drive, Lake Oswego, OR 97035-2406; (503) 699-9836
Dr. Peet M. Soot, Principal Investigator
Dr. Peet M. Soot, Business Official
DOE Grant No. DE-FG03-95ER82041
Amount: $75,000

This project will use of pressure swing adsorption, a batch operation suitable for binary gas mixtures, to separate multi-component gas mixtures into their respective components. This is a new processing concept for gas separations that will allow for the removal of CO_2 and N_2 from natural gas simultaneously, obviating the need for multiple process steps. The fundamental concept of pulsed flow adsorption columns (PFAC) is an extrapolation of work found in the literature on a process called parametric pumping. This concept calls for rapid cycling of an internal variable such that bulk separation of components is effected on a continuous basis. It has been proven to be effective in a number of liquid and gaseous systems. Phase I will take this concept through mathematical modeling and laboratory testing. A bench-scale pilot plant unit will be built and operated in Phase II, and commercial demonstration and implementation is expected to follow in Phase III.

Anticipated Results/Potential Commercial Applications as described by the awardee: Application of this process to the Nation's non-pipeline quality gas resources will demonstrate of PFAC's commercial potential. Over 100 trillion cubic feet of the domestic natural gas reserves are low quality. PFAC will provide a nitrogen/carbon dioxide rejection process which can change these unused resources into a supply capable of matching the entire Nation's domestic natural gas production for up to 10 years.

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Aggressive, Abrasion-Resistant Cutters for Hard Rock Drill Bits--Novatek, 2185 South Larsen Parkway, Provo, UT 84606-6218; (801) 374-6000
Mr. David R. Hall, Principal Investigator
Mr. David R. Hall, Business Official
DOE Grant No. DE-FG03-95ER82043
Amount: $74,907

In medium-to-hard abrasive rock formations, rate of penetration is often slow because of wear and breakage of cutters in the drill bit. Percussion bits are particularly sensitive to cutter wear since such bits cannot be used to ream undergauge holes. Polycrystalline diamond technology has been applied successfully to protect percussion bits from wearing at accelerated rates in abrasive formations. However, application of the diamond coated cutters to hard rock formations has been limited by weak diamond-to-diamond bonding and degradation of the basic tungsten carbide cutter substrate by diamond processing. Moreover, diamond coated cutters have not achieved their potential in providing wear resistance due to weak bonding. The planned research effort will investigate the feasibility of applying a novel, patented diamond composite material to a percussion bit cutter. This diamond composite has shown in preliminary tests a superiority in wear resistance and bone integrity over prior art diamond coating materials. In Phase I, new, proprietary processing techniques will be used to optimize bulk cutter strength. Composite layer composition and structure will also be optimized to provide for optimal wear resistance and impact strength. The overall goal of this research is to provide a cutter structure that exhibits sufficient toughness to extend the usefulness of diamond coating technology to more severe applications. Phase II research will therefore investigate sharper, higher stress cutter applications. Success in these applications may lead to novel, cost-reducing insert designs.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is expected that the design and optimization efforts outlined above will provide industry with a new generation of diamond enhancement products for drill bits. These products are expected to increase rate of penetration over that obtained by prior art diamond enhanced bits by more aggressively attacking the rock formation. They are expected to increase bit life by providing more competent diamond bonding and higher wear resistance. The products are also expected to expand the usefulness of diamond enhanced cutters into harder rocks than are currently drillable with diamond inserts.

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Development and Testing of a Down-hole Mud Actuated Hammer--Novatek, 2185 South Larsen Parkway, Provo, UT 84606-6218; (801) 374-6000
Mr. David R. Hall, Principal Investigator
Mr. David R. Hall, Business Official
DOE Grant No. DE-FG03-95ER82042
Amount: $75,000

The high cost of drilling gas wells worldwide has prompted the gas industry to seek more efficient and economical means of reaching natural gas pay zones. Particular focus has long been focused on increasing the rate-of-penetration of drilling tools. Drilling by percussion methods has dramatically improved penetration rates in some applications where air is used as the drilling fluid. However, air cannot be used in all applications because of water production, or for well control or safety reasons. For many years, innovators have tried to develop a percussion drilling tool actuated by drilling mud. However, the incompressible and abrasive nature of drilling mud has caused each of these efforts to fail to produce an economical tool. A prototype tool with many novel and innovative design features has been developed. In laboratory testing this tool has shown promise in providing consistent and sustained operation. Initial testing of this tool in a deep gas well has led to the conclusion that a higher energy tool is needed to provide adequate increases in the rate of penetration. In Phase I, a new tool will be designed and built, based on previous laboratory and field experience. This tool will then be tested in a laboratory setting to determine its benefits over conventional rotary drilling. Basic operating effectiveness will be measured as functions of supply pressure and weight on the bit. Should benefits over conventional drilling be measured in Phase I tests, Phase II testing will include laboratory and field tests and will catalog benefits and optimal operating parameters in various rock formations.

Anticipated Results/Potential Commercial Applications as described by the awardee: With successful completion of Phase I and II efforts, a characterized, effective tool will be available to industry which will offer significantly reduced costs of drilling wells where drilling mud is used as the fluid. Cost reducing features are expected to include an increase in penetration rate, a decrease in hole deviation, and an increase in bit footage. Well safety may also be enhanced by encouraging the use of mud drilling in potentially dangerous wells.

158

High Resolution Seismic Modeling and Analysis of Fractured Reservoirs--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143-4228; (617) 547-1122
Mr. Stephen Theophanis, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-95ER82066
Amount: $74,998

Economically viable extraction from low permeability natural gas reservoirs, such as tight sand reservoirs, requires methods for accurately analyzing fracture content. In these reservoirs, fractures have a dominant influence on the movement of gas within the formation. Seismic experiments can yield valuable data on the distribution and orientation of fracture systems based on the anisotropy frequently associated with naturally occurring fracture zones. However, the analysis and interpretation of such seismic data are difficult, especially in regions where there is significant geological structure. Accurate and rapid methods for simulating the seismic response of the gas reservoir would be invaluable in interpreting and utilizing a high resolution data set. Several theoretical and numerical methods have been proposed recently for modeling seismic wave propagation in such media, including finite difference simulations. While the finite difference method is, in principle, exact and can model very general three dimensional structures, it is extremely intensive computationally. In contrast, the ray-Born method, a hybrid solution combining high speed ray tracing with analytical approximations, is less accurate but very rapid. A major issue involved with this latter method is the development of an adequate understanding of its accuracy limitations. In Phase I, a detailed assessment of the value of such seismic modeling technology will be performed by comparing laboratory scale model results for specific simulated fracture systems. The ray-Born solution will be compared with observations from ultrasonic wave recordings from laboratory models of elastic wave reflections from anisotropic obstacles representing fractured reservoirs. The principal goal of this investigation is to determine the utility of the high speed ray-Born algorithm in the future development of software packages for the analysis of three dimensional, high resolution, seismic data sets. Phase II will proceed with the implementation of these algorithms in forms that will be integrated into seismic data processing systems currently used by companies in the gas industry.

Anticipated Results/Potential Commercial Applications as described by the awardee: With successful development of the ray-Born method, the gas industry will be able to obtain accurate characterization of reservoirs, especially in defining the distribution and properties of fracturing. The method has the potential to improve economic feasibility for new natural gas field exploration by developing software to implement the ray-Born method and benchmarking the algorithms on which this software is based.

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Small Scale Recovery of Sulfur from Sour Gas--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033-1916; (303) 940-2301
Dr. Girish Srinivas, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-95ER82088
Amount: $75,000

Natural gas provided 30% of the energy consumed in the United States in 1992. Unfortunately, almost 20% of the U.S. gas reserves are sour (contaminated with hydrogen sulfide (H_2S)). Because of its acidic nature and corrosiveness, the H_2S content of gas entering pipelines must be lower than four ppm. Therefore, H_2S removal is one of the main processes in gas processing plants. It is estimated that a substantial portion of the new gas treatment facilities will be small-scale units, recovering less than 10 tons per day of sulfur. At this scale, the Claus plant is extremely uneconomical and liquid redox systems are being used for small-scale sulfur recovery. Liquid processes are the sulfur recovery systems of choice. Unfortunately, liquid redox systems are expensive and have operational difficulties such as solvent disposal problems and processing of the recovered sulfur. This project will develop a small-scale sulfur recovery process based on a selective oxidation process that converts H_2S to sulfur using a solid catalyst. In Phase I, the activity and selectivity of the catalysts will be investigated as a function of temperature, catalyst composition, and reactant concentration. Engineering analyses will also be carried out to compare these novel catalyst systems with current liquid redox and solid catalytic systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The immediate application for an H_2S selective oxidation catalyst is in the sulfur recovery from small-scale sour gas processing plants. The catalytic process can also be used as a Claus tail-gas treatment process for sulfur recovery from refineries, offshore platforms, coal gasifiers, and water treatment plants.

NATURAL GAS UTILIZATION

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A Tubular Intermediate Temperature Natural Gas Fuel Cell Incorporating a Perovskite Solid Electrolyte--Eltron Research, Inc., 2830 Wilderness Place, #E, Boulder, CO 80301-5455; (303) 440-8008
Dr. Anthony F. Sammells, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG03-95ER81960
Amount: $74,995

There are strong incentives to develop solid oxide fuel cells (SOFCs) which utilize natural gas as a fuel and which operate at lower temperatures than those based upon the solid electrolyte yttria stabilized zirconia (YSZ). New solid electrolytes would be required which possess, at intermediate temperatures (650°C to 750°C), ionic conductivities similar to those currently found with YSZ at 1000°C. Such fuel cells would achieve higher energy conversion efficiencies and impose less severe materials constraints upon SOFC hardware than current systems. For example, fuel cells operating at 750°C and below would require only relatively inexpensive stainless steel hardware components for their implementation. This project will be directed towards the fabrication and performance evaluation of such intermediate temperature SOFCs. Specific Phase I tasks are: (1) prepare selected pervoskite powders followed by their subsequent fabrication into oxygen anion conducting solid electrolyte disks, (2) deposit cathode electrocatalysts, (3) deposit anode electrocatalysts, (4) incorporate resulting fuel cell disks into an appropriate hardware test configuration, (5) perform electrochemical half-cell measurements to clarify individual electrode overpotential and overall internal resistance losses through the solid electrolyte, (6) perform fuel cell electrochemical testing as a function of fabrication procedures, operating temperature, and other experimental variables to determine long-term performance viability, and (7) incorporate preferred components into tubular fuel cell configurations and determine their electrochemical performance.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of this project will result in the identification of intermediate temperature fuel cell components compatible with the efficient utilization of natural gas-based fuel cells for electricity generation. Full implementation of this technology would provide significant economic and technical benefit to the Nation by substantially lowering electricity costs with a domestically available fuel source.

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In-Situ Electrolyte Replenishment for Long Fuel Cell Life--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 825-6006
Dr. Lawrence Paetsch, Principal Investigator
Dr. Hans C. Maru, Business Official
DOE Grant No. DE-FG02-95ER81966
Amount: $74,987

The attractiveness of carbonate fuel cell power plants can be significantly enhanced by extending the life of the fuel cell and lowering the cost. The electrolyte inventory plays the most important role in controlling useful life and maintaining beginning-of-life (BOL) performance level. During operation, the fuel cell loses electrolyte through cathode side hardware corrosion reactions, wetting and absorption on the hardware oxide scale, and evaporation in the reactant gas streams. Significant electrolyte loss can cause matrix drying, resulting in increased gas cross leakage, electrode polarization, and ohmic resistance. Therefore, it is desirable to devise an approach to compensate for electrolyte loss during fuel cell operation to extend the useful life of the cell well beyond the present goal of 40,000 hours. This would also have a positive impact on fuel cell cost reduction by allowing thinner active cell components. The goal of this project is to provide cost-effective, in-situ replenishment of electrolyte in the carbonate fuel cell to compensate for the expected losses. The replenishment will be engineered to take place when the major losses have occurred but before matrix drying effects become pronounced. An appropriate design will be identified and tested in out-of-cell tests during Phase I. The concept will be implemented in stack testing during Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The ultimate objective of this research is to develop a cost-effective, in-situ electrolyte replenishment to compensate for electrolyte loss. The proposed research will extend carbonate fuel cell life well beyond the present goal of 40,000 hours and at the same time reduce cost, which would help accelerate the commercialization of this unique technology. The electrolyte replenishment approach will also be beneficial to other types of fuel cells.

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A Lower Cost Molten Carbonate Matrix--M-C Power Corporation, 8040 South Madison Street, Burr Ridge, IL 60521-5808; (708) 986-8040
Mrs. Diane S. Erickson, Principal Investigator
Mr. Patrick F. McSweeney, Business Official
DOE Grant No. DE-FG02-95ER82014
Amount: $74,858

Molten carbonate fuel cell (MCFC) powerplants have the potential for providing clean, efficient dispersed and central power generation if costs can be reduced and performance improved. This project addresses both cost and performance of the MCFC power module (the stack) by utilization of low cost matrix raw materials and elimination of processing steps. Chemical processing methods of ceramic powder production have been demonstrated in the laboratory for manufacturing the MCFC matrix materials. This Phase I project will demonstrate the optimal route for lowering the cost of the MCFC matrix. The feasibility of scaling up two lower cost matrix manufacturing processes will be investigated. One option involves chemical powder synthesis from lower cost starting materials followed by traditional forming techniques. The other option involves an innovative process which combines the chemical powder synthesis procedures with tape casting procedures currently in use for commercial production of full area (one m^2) MCFC matrix layers. Because of the significantly lower raw materials costs and the elimination of manufacturing steps, the cost of the MCFC matrix will be significantly reduced. A cost comparison between the state-of-the-art matrices with the lower cost alternatives will also be generated as part of the Phase I effort.

Anticipated Results/Potential Commercial Applications as described by the awardee: The cost of the lithium aluminate electrolyte support matrix will be reduced dramatically, resulting in a significant reduction in the cost of the MCFC stack. The new process will also reduce work-in-process inventory.

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Fabrication of Multi-layer Molten Carbonate Fuel Cell Composites--M-C Power Corporation, 8040 South Madison Street, Burr Ridge, IL 60521-5808; (708) 986-8040
Mrs. Diane S. Erikson, Principal Investigator
Mr. Patrick F. McSweeney, Business Official
DOE Grant No. DE-FG02-95ER82013
Amount: $74,470

Molten carbonate fuel cell (MCFC) powerplants have the potential for providing clean, efficient dispersed and central power generation if costs can be reduced and performance improved. The effort planned herein addresses both cost and performance of the MCFC power module (the stack) by manufacture of multilayer active components preconditioned prior to assembly. In Phase I, techniques for tape casting multilayer MCFC active area components will be developed at the laboratory scale (1% of commercial scale). Out-of-cell preconditioning (removal of organics) will be demonstrated followed by characterization of the cell packages for cell testing under Phase II. Phase I work will also investigate alternate cutting techniques to replace the current steel-rule die cutting which may cause component cracking or separation of the multilayer active area components.

Anticipated Results/Potential Commercial Applications as described by the awardee: The cost of fuel cell technologies inhibits widespread use of fuel cell power plants. The successful completion of this project will lead to a cost effective power plant that can be used in distributed generation applications. This will result in increased energy efficiency of the power industry and decreased environmental emissions.

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Low Cost Molten Carbonate Fuel Cell Anodes--
M-C Power Corporation, 8040 South Madison Sreet, Burr Ridge, IL 60521-5808; (708) 986-8040
Mrs. Diane S. Erickson, Principal Investigator
Mr. Patrick F. Sweeney, Business Official
DOE Grant No. DE-FG02-95ER82015
Amount: $74,982

Molten carbonate fuel cell (MCFC) powerplants have the potential for providing clean, efficient, dispersed and central power generation if costs can be reduced and performance improved. This project addresses both cost and performance of the MCFC power module (the stack) by combining anode processing steps and by strengthening the anode to allow removal of the current collector. Phase I will investigate the feasibility of scaling up a novel manufacturing technique for lowering the cost of the high performance MCFC anode. Currently, because of the stringent microstructural requirements of the anode, MCFC developers must utilize expensive pre-alloyed powders to obtain an anode with sufficient creep resistance. This novel manufacturing process combines traditional pack cementation alloying methods with the tape casting and sintering procedures currently used for manufacturing commercial-area (one m^2) MCFC anodes. Homogeneous dispersions of small amounts of the alloying metal are possible with microstructures not possible using prealloyed powders. Improvements in the anode strength is anticipated at a lower cost for the anode, as is further stack cost reduction by removal of the anode current collector.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result is a significant reduction in the cost of MCFC stacks by combining anode processing steps and removing the anode current collector. The reduction in stack costs should have a positive impact on MCFC power plant costs and should improve the competitive position of this technology relative to other generation technologies and foreign competition.

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Nanostructured Thermal Barrier Coatings for Natural Gas-Fired Advanced Turbines--
Nanomaterials Research Corporation, 10960 North Stallard Place, Tucson, AZ 85737-9527; (602) 575-1354
Dr. Tapesh Yadav, Principal Investigator
Dr. Angelo Yializis, Business Official
DOE Grant No. DE-FG03-95ER82035
Amount: $75,000

The ready availability of clean natural gas at low prices has been a major factor in the increased use of gas turbines. Recent projections suggest that, over the next 10 years, advanced gas turbines and combined cycles will be the leading power generation technology and would account for 45% of the global capacity additions. It is envisaged that improvements in advanced gas turbine efficiencies will require turbine components that can perform at higher inlet temperatures. This, in turn, requires that material technology be developed that can enable the anticipated increases in the turbine operating temperature. This project seeks to investigate and develop nanostructured thermal barrier coatings for advanced natural gas-fired turbines. Nanostructured coatings are coatings based on powders with nanoscale (10^{-7} to 10^{-9} m) dimensions. This technology may enable the application of these coatings for turbine blades and vanes while minimizing the adverse centrifugal loads that are presently unavoidable. The technical approach during Phase I would establish the proof-of-concept. Phase II will optimize the technology, develop prototype components, and field test the components with potential customers. Phase III will commercialize the technology.

Anticipated Results/Potential Commercial Applications as described by the awardee: Thermal barrier coatings are of extreme importance to future land-based gas turbines. Nanostructured coatings may help enhance the shielding of turbine components such as the combustor, turbine blades, vanes, and transition pieces from much higher turbine operating temperature. This could help the realization of desired 50% to 60% range efficiencies in advanced combined cycle gas turbine systems.

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An Advanced Technology Catalytic Combustor for Natural Gas Turbine Engines--Precision Combustion, Inc., 25 Science Park, New Haven, CT 06511-1968; (203) 786-5215
Dr. William C. Pfefferle, Principal Investigator
Mr. J. Kevin Burns, Business Official
DOE Grant No. DE-FG02-95ER82054
Amount: $75,000

The development of a novel advanced technology catalytic combustor (ATCC) is planned as an enabling technology for ultra-high efficiency, environmentally-superior, cost-competitive, ground-based natural gas turbine engine systems. Design innovations will overcome the limitations of earlier catalytic combustor designs with ultra-low emissions (e.g., 1 ppmv NO_x and less than 5 ppmv CO at advanced turbine system conditions), high combustion stability, operability without a preburner, high turndown, and long term durability. In Phase I, one or more laboratory prototypes incorporating this technology will be built and demonstrated at atmospheric pressure in concert with design explorations. In Phase II, a full scale combustor will be developed and demonstrated at full system pressure in preparation for Phase III engine testing.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful development would provide a U.S.-based ground power generation gas turbine technology offering ultra-high efficiency and ultra-low emissions at reasonable cost and without aftertreatment. Such gas turbine engines are expected to comprise a significant domestic and export market into the 21st century.

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Improved Solid Oxide Fuel Cell Seals--Technology Management, Inc., 9718 Lake Shore Boulevard, Cleveland, OH 44108-1049; (216) 541-1000
Dr. James White, Principal Investigator
Mr. Benson P. Lee, Business Official
DOE Grant No. DE-FG02-95ER82094
Amount: $74,928

Sealing between multiple cell layers is critical to planar solid oxide fuel cell (SOFC) operation. The planned research will study new ceramic-filled glass composite materials for the SOFC seal that maintains structural integrity during long-term operation and through thermal cycles. The glass composites will also be doped with various materials to minimize material interactions. The SOFC design is based on compliant electrodes which accommodate the thermal expansion mismatch between the zirconia electrolyte, electrodes, and interconnect. However, it demands a seal that maintains structural integrity of manifolds and does not adversely interact with the zirconia electrolyte of the metal-alloy interconnect. Phase I research will identify and show proof-of-concept of ceramic-filled glass composite materials which minimize interaction between materials while maintaining structural integrity without a decrease in cell performance of SOFCs.

Anticipated Results/Potential Commercial Applications as described by the awardee: After demonstrating the feasibility of using glass-ceramic seals in Phase I, research and development will be expanded in Phase II to optimize and test the materials in multi-cell fuel cell stacks and begin fabrication and engineering development which will lead to a breadboard prototype. Applications include remote and distributed, commercial and residential electric power generation, including commercial cogeneration, and mobile/portable applications.

ADVANCED COAL-BASED POWER SYSTEMS

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A Cost Efficient Method for Producing Ceramic Composites for Coal-Fired Furnace Applications--Advanced Refractory Technologies, Inc., 699 Hertel Avenue, Buffalo, NY 14207-2341; (716) 875-4091
Mr. Thomas J. Mroz, Principal Investigator
Mr. Keith A. Blakely, Business Official
DOE Grant No. DE-FG02-95ER81912
Amount: $75,000

The corrosive, high temperature environment in coal burning plants puts a tremendous burden on materials selection and engineering. For example, in gas turbine power generation, improved heat exchangers are needed to efficiently transfer heat energy while containing dirty combustion exhaust. Existing materials cannot meet the increasingly difficult demands of these applications. As temperature requirements increase, the probability of structural and corrosion related failure also increases. Development of new materials, composites in particular, will be required. Composites of aluminum nitride (AlN) and silicon carbide (SiC) have recently been shown to have good oxidation performance and to exhibit corrosion resistance in the coal exhaust stream environment. While early samples of these composites have been prepared by hot pressing, pressureless sintering may provide composites with lower fabrication costs. This Phase I effort will evaluate the application of an existing, low cost, industrial scale process to the preparation of an AlN-SiC composite composition. This process is already used in the industry to prepare large components at relatively low costs. However, for industrial use in heat exchangers and similar applications, fabrication costs may need to be reduced further. Initial evaluation of the resulting composite for simple thermochemical properties will also be performed in Phase I. In Phase II, scale-up of the process to produce large parts will be performed, as well as more complete testing of the composite for mechanical and thermal properties.

Anticipated Results/Potential Commercial Applications as described by the awardee: AlN-SiC composites are expected to find widespread use in coal power generation applications, particularly heat exchangers. Other coal applications may include hot gas particulate filters. Other non-coal corrosion applications such as refractories for metals and molten salts may also be of interest.

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A Plasma Driven Ultra Low Nitrogen Oxide Pulverized Coal Combustor--Busek Company, Inc., 19 Kearney Road, Needham, MA 02194-2505; (617) 449-3929
Dr. V. Hruby, Principal Investigator
Mrs. J. Budny, Business Official
DOE Grant No. DE-FG02-95ER81936
Amount: $74,999

To obviate the requirement for capital and energy intensive backend flue gas treatment to meet emerging Federal emission standards, a novel, ultralow nitrogen oxide (NO_X) pulverized coal combustor will be developed. The concept is applicable to retrofit and new capacity wall-fired and tangentially-fired utility boilers, and industrial boiler systems. The concept focuses on a novel method of controlling the stoichiometry, kinetics, and fuel-bound nitrogen evolution in the fuel devolatilization and initial combustion stages. An extremely fuel-rich reaction zone is sustained by the low temperature, highly oxidizing plasma environment. The plasma contains highly reactive oxygen radicals and permits fuel devolatilization at stoichiometries where fuel-bound nitrogen conversion to non-oxide compounds is favored. The power consumption to create the plasma is less than 0.5% of the thermal input of the combustor. Proven thermal management techniques for primary zone combustion limit the formation of thermal NO_X which results in NO_X emissions several times lower than in commercially available low NO_X burners. In Phase I, previous experience with plasma ignition and rapid devolatilization of pulverized coal will be expanded and the feasibility of the concept demonstrated. Experiments will be performed to measure NO_X emissions and power consumption as a basis for the design of a 6 mmBtu/hour combustor. In Phase II, the combustor will be constructed and tested in an actual boiler.

Anticipated Results/Potential Commercial Applications as described by the awardee: Simple modifications to the combustion process that will help achieve environmental compliance have the greatest chance for industry acceptance and market penetration. The successful development of the ultralow NO_x combustor would allow utilities to approach compliance with emerging Federal NO_x emissions standards without recourse to backend flue gas treatment, fuel switching, or unit derating. The concept is amenable to wall-fired, tangentially-fired, and industrial boilers for both retrofit and new capacity applications.

170

An Intumescent Mat Material for Joining of Ceramics to Metals at High Temperatures--CeraMem Corporation, 12 Clematis Avenue, Waltham, MA 02154-7035; (617) 899-0467
Dr. Robert J. Higgins, Principal Investigator
Dr. Robert L. Goldsmith, Business Official
DOE Grant No. DE-FG02-95ER81939
Amount: $75,000

In advanced coal-based power systems that involve temperatures up to 1000°C, the sealing of ceramic components, such as particulate filters and heat exchangers, into fixtures composed of high temperature alloys is exceptionally difficult. This is due to the large disparity in the thermal expansion coefficients of these two classes of materials. The requirement to seal large gaps between ceramic and metallic components at elevated temperatures, coupled with the need to maintain appropriate stress levels on the ceramic component at all temperatures, places extreme demands on the properties of the material used to seal the ceramic-metallic gap. In analogous systems at somewhat lower temperatures, vermiculite-based intumescent mats are utilized as gap-filling materials. However, such mats degrade above about 800°C and may in fact have limited lifetime when used above 500°C. The objective of this project is to develop methods for fabricating ceramic-metallic joining compounds at 1000°C. The high temperature mat materials to be developed are based on multilayer biceramic composites that can reversibly expand and contract between room temperature and 1000°C. These composites will incorporate combinations of high-temperature oxides, to be fabricated by surface modification treatments of thin, tape-cast ceramic sheets. In Phase I, several modification techniques and oxide combinations will be investigated. Multilayer biceramic composites will be fabricated using preferred compositions and processing techniques and evaluated for relevant thermomechanical properties.

Anticipated Results/Potential Commercial Applications as described by the awardee: The high temperature expanding mat would greatly improve the mechanical joining of ceramic parts to metallic components and systems. Ceramic components could be mounted into hot gas filtration systems, heat exchangers, high temperature vehicle emissions control systems, and heat protection/control systems for advanced jet engines. The mat could reduce the cost of joining ceramic to metal parts providing more cost-effective systems than those joined by other methods.

171

A New and Low Cost Process to Decompose Ammonia in Integrated Coal Gasification Combined-Cycle Fuel Gas Streams--Energy and Environmental Technology Corporation, 11609 Treviso Way, Rancho Cucamonga, CA 91701-8697; (909) 466-6266
Dr. Shaik A. Qader, Principal Investigator
Dr. Shaik A. Qader, Business Official
DOE Grant No. DE-FG03-95ER81964
Amount: $75,000

The integrated coal gasification combined cycle (IGCC) process has the potential to emerge as a high efficiency and environmentally clean technology. In the IGCC process, coal is converted to a gas which is used as a fuel to generate power in a gas turbine combined cycle system. Coal gas contains ammonia which is converted to nitrogen oxides (NO_x) in the gas turbine, and the removal of NO_x from gas turbine exhaust is expensive. Removal of ammonia from coal gas prior to combustion in the gas turbine lowers costs and improves the overall efficiency of the IGCC process. A new and low cost process is being developed to decompose the ammonia present in coal gas to nitrogen. This process operates at high temperatures and high pressures, and has the potential to reduce ammonia concentration to one part per million. The process uses a chemical reagent which decomposes ammonia to nitrogen and increases the heating value of coal gas, which in turn increases output of the IGCC power plant. During Phase I, ammonia decomposition tests will be performed under different conditions to establish the technical feasibility of the process. The test data will be used to develop a design basis and make a preliminary cost estimate.

Anticipated Results/Potential Commercial Applications as described by the awardee: The ammonia decomposition process lowers IGCC technology costs and improves the quality of the environment. The process has good commercialization potential for IGCC power plant applications.

172

An Improved Material and Low-Cost Fabrication Options for Candle Filters--FluiDyne Engineering Corporation, 5900 Olson Memorial Highway, Minneapolis, MN 55422-4999; (612) 544-2721
Mr. Steven D. Hickel, Principal Investigator
Dr. Gary J. Hanus, Business Official
DOE Grant No. DE-FG02-95ER81971
Amount: $74,960

Ceramic candle filters are currently being developed for removal of particulates from hot flue gas. Commercialization of this technology will be enhanced and accelerated if the candle costs can be reduced. Cost is especially important for pressurized fluidized bed combustion plants because of the large number of candles needed. Substantial cost reductions are possible by the use of an innovative method of fabricating ceramic components, called self-propagating high-temperature synthesis (SHS). Hot-gas cleanup is a growing need throughout most of the world, and successful implementation of SHS in this application will present substantial export potential. SHS is based on exothermic chemical transformations in powder media. Ignition of a powder mixture in a vessel produces a self-sustaining combustion wave. Reaction occurs in the combustion wave resulting in the synthesis of the materials in the mixture, eliminating the need for firing in kilns. Shapes can be fabricated to final dimensions in a short time. SHS reduces the processing and quality control costs, which are significant for ceramic components. SHS also provides control of porosity, making it especially suited to manufacturing filters. Phase I focuses on identifying materials suitable for hot gas cleanup systems using SHS. Material samples will be fabricated and tested for filter performance. The feasibility of manufacturing full-size filters using SHS will be determined.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is expected that several important results will be derived from the project when successfully completed. Ceramic candles made by the SHS innovative fabrication technique will be commercially available for sale to users worldwide. These candles will have high filtration efficiency, low cost, and long life. They will be available in different materials to provide the most cost effective systems for a particular application. Sales will be to manufacturers of hot-gas cleanup systems, to chemical, waste disposal, incineration, and metallurgical industries, and to any industries where high temperature gas filtration will improve process efficiency and reduce emissions.

173

A Device to Increase Candle Filter Failsafe Protection and Jet Pulse Cleaning Effectiveness in Pressurized Fluidized-Bed Combustion Processes--Industrial Filter and Pump Manufacturing Company, 5900 Ogden Avenue, Cicero, IL 60650-3888; (708) 656-7800
Mr. Paul M. Eggerstedt, Principal Investigator
Mr. Jeffrey Burgeson, Business Official
DOE Grant No. DE-FG02-95ER81995
Amount: $75,000

Ceramic candle filtration is an attractive technology for the removal of particulates at high temperature in coal combustion processes. Because of their simple, cost effective design, high temperature capability, and effectiveness in filtration, ceramic candles easily achieve New Source Performance Standards, Clean Air Act, and gas turbine manufacturer particulate requirements. Little progress, however, has been made in two important operational areas of ceramic candle filtration, namely, optimizing jet pulse cleaning effectiveness and system fail-safe protection in the event of a catastrophic candle failure. Preliminary research at ambient conditions has succeeded in the prototype development of a jet pulse enhancement device. During jet pulse cleaning, a slight restriction immediately downstream of a filter candle will momentarily become very large, resulting in a reversal of as much as two to three times more cleaning gas through the filter candle with a proportional increase in overall cleaning effectiveness. By properly selecting the particle retention, surface area, and pressure drop characteristics of the restrictive device, independent fail-safe protection can also be provided to each filter candle individually. Phase I will focus on the optimum design and development of such a device, suitable for scale-up, to provide fail-safe protection and enhanced jet pulse cleaning of filter candles at ambient conditions. Utilizing existing large scale filtration equipment, Phase II tests will be conducted at 1700°F, under simulated combustion conditions, to develop the device for commercial use.

Anticipated Results/Potential Commercial Applications as described by the awardee: By increasing jet pulse intensity, reducing pulse gas volume requirements, and acting as a fail-safe trap to prevent candle debris and dust from damaging downstream equipment in the event of a candle failure, filter performance and process efficiency will increase while the potential for downstream component failure and process interruptions will be minimized. Such enhanced cleaning and fail-safe protection is of particular importance in coal utilization processes, where dust cakes are often cohesive and difficult to remove, and where protection of components downstream of the filter station is critical.

174

A Continuous, On-Line, and Real-Time Optical Diagnostic System for Monitoring, Characterization, and Control of Toxic Air Emission--M. L. Energia, Inc., P.O. Box 470, Princeton, NJ 08542-1468; (609) 799-7970
Dr. Moshe Lavid, Principal Investigator
Ms. Nira Lavid, Business Official
DOE Grant No. DE-FG02-95ER82016
Amount: $75,000

Successful commercialization of advanced coal-based power generating systems requires compliance with environmental emission control regulations. However, current systems for monitoring emissions are expensive, delicate, and cumbersome. Furthermore, none of the existing techniques offers continuous, on-line, and accurate measurements. Phase I offers an innovative technique, based on infrared spectrometry, which combines the simplicity of a circular variable filter with the high resolution of a fine-tuned optical spectrum analyzer. Phase I is a proof-of-concept experimental effort. A breadboard instrument will be designed, fabricated and assembled. Representative gaseous pollutants will be used to determine sensitivity and accuracy. Multivariate chemometric methods will be employed for multispecies mixtures. Phase I will provide the impetus as well as the technical basis for Phase II, during which a prototype instrument will be designed, constructed, and fully tested. It will be followed by a full-scale commercialization (Phase III).

Anticipated Results/Potential Commercial Applications as described by the awardee: This project offers a unique diagnostic instrument for on-line, continuous, real-time, affordable, and accurate monitoring of hazardous pollutants discharged to the environment by various combustion and chemical processes. It will facilitate environmental compliance by monitoring, characterizing, and controlling gaseous emissions from industrial processes.

175

Abrasive-Waterjet Machining Techniques for Ceramic-Material Coal-Based Power System Components--Quest Integrated, Inc., 21414 68th Avenue South, Kent, WA 98032-2439; (206) 872-9500
Dr. Corey M. Dunsky, Principal Investigator
Ms. Diana J. Suzuki, Business Official
DOE Grant No. DE-FG03-95ER82059
Amount: $74,945

New methods of utilizing coal hold the promise of meeting a significant portion of increasing demands for electrical power. Many of the designs for new coal-based power generating equipment (advanced turbines, externally fired combined cycle engines, pressurized fluidized bed combustors) feature components fabricated from advanced ceramic materials. While ceramics are excellent materials for components subjected to the harsh, high temperature environments in many power generation subsystems, they are costly to produce. The high production cost is due mainly to the difficulties of machining ceramic parts. Recent developments have advanced ultrahigh-pressure abrasive waterjet (AWJ) technology, formerly a cutting process, into the area of machining. This offers the possibility of cost-effectively machining difficult materials such as ceramics. This proposal addresses the feasibility of machining ceramic components for coal fired heat engines. In Phase I, ceramic components used in current or near-term coal-fired heat engine systems will be selected and AWJ machining process development for these components will be carried out. The cost and technical performance of AWJ machining of these example parts will be compared with conventional machining methods. Materials and geometries for which AWJ machining offers significant advantages will be identified, as well as necessary specialized tooling for the development of a flexible, integrated AWJ ceramic machining tool in Phase II of the project.

Anticipated Results/Potential Commercial Applications as described by the awardee: Advanced ceramic materials are being incorporated into many developing high temperature technologies in energy conversion, transportation, and defense. However, ceramics are costly due the difficulty of machining component parts. New abrasive waterjet (AWJ) machining technology offers a possible method of economically machining these materials. The application of this technology to the fabrication of component parts for power generation equipment could significantly reduce capital costs of commercial-scale systems. More generally, successful development of a cost-effective means of machining ceramics would result in increased use of these materials in the aerospace, automotive, electronics, and medical sectors.

176

A Novel Fabrication Process to Enable Joining of Ceramics and Intermetallics--T/J Technologies, Inc., 17445 Cameron Drive, Northville, MI 48167-3253; (810) 347-0305
Dr. Inyoung Song, Principal Investigator
Ms. Maria A. Thompson, Business Official
DOE Grant No. DE-FG02-95ER82086
Amount: $75,000

Operating temperatures and stress levels imposed on advanced power system components have been continually increasing. So, too, has the difficulty of fabricating reliable joints between the high performance refractory materials comprising these components. Recent developments suggest that functionally gradient interfaces possess improved material properties that will enable joining of ceramics to ceramics or ceramics to metals. This project consists of an innovative and cost-effective process for making functionally gradient composites by combining the self-propagating high-temperature synthesis (SHS) process with a proprietary consolidation process. The planned approach can be used in the fabrication of a variety of shapes, including tiles, rods, tubes, tapes, and more complex geometries. This approach addresses both the high cost, low throughput limitations of previous attempts which combined SHS with static compaction processes and the poor process control and environmental liabilities of combining SHS with explosive compaction. In Phase I, the approach will first be demonstrated by fabricating a fully dense monolithic component from a difficult-to-consolidate powder precursor. This will be followed by the fabrication of a fully densified functionally gradient component, varying from a thermally stable ceramic front face to a fully metallic backing. The components will be characterized so that their mechanical properties can be related to systematically varied process control variables. In Phase II, the process will be extended to additional materials systems in order to demonstrate near-net shape capabilities. High temperature stress measurements and related functional tests will also be performed.

Anticipated Results/Potential Commercial Applications as described by the awardee: Application of functionally gradient materials will improve the reliability and increase the operating temperature of advanced power system components. Increased operating temperatures will significantly improve energy efficiency, generating savings in the cost of electricity and limiting the depletion of fossil fuel reserves. Other prospective applications include automobile components, hypersonic vehicles, slurry transport equipment, and fusion energy reactors.

177

A Novel Desulfurization Sorbent--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033-1916; (303) 940-2301
Dr. Robert Copeland, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-95ER82090
Amount: $75,000

While coal fired gasifier combined cycles (GCC) have both high efficiency and very low emissions, there is critical need to remove hydrogen sulfide (H_2S), produced from the sulfur in the coal, from the hot gases. There has been extensive research on hot gas clean-up systems using zinc oxide based sorbents (such as zinc titanate). Zinc titanate can remove sulfur to extremely low levels; however, improved sorbents are still needed because the current formulations degrade rapidly as they are cycled. A new sorbent structure and fabrication method has been identified which produces sorbent pellets with greatly increased lifetimes. When this structure was used with a tin oxide sorbent, the pellets had a very long lifetime under hot gas cleanup conditions. The sorbent fabrication should be readily adaptable to the production of long-life zinc oxide sorbents for use in fluidized bed hot gas cleanup systems. In Phase I, the adaptation of this process to the zinc oxide sorbent for fluidized bed applications will be demonstrated. The previous sorbent composition will be modified, the cyclic life measured for a minimum of 10 cycles, and the sorbent tested in a fluidized bed reactor under simulated hot gas cleanup conditions.

Anticipated Results/Potential Commercial Applications as described by the awardee: This new method of producing the sorbent will reduce the cost of hot gas cleanup of H_2S by increasing the life and decreasing the cost of the zinc oxide sorbent. The new production process may be applicable to other absorbant applications. The low cost, long life sorbent will reduce the cost of hot gas cleanup H_2S sorbents and improve the economics of gasifiers used for combined cycle or fuel cell power generation or fuel and chemicals production.

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Advanced Hot Gas Filter Development--Ultramet, 12173 Montague Street, Pacoima, CA 91331-2210; (818) 899-0236
Mr. Andrew J. Sherman, Principal Investigator
Mr. Craig N. Ward, Business Official
DOE Grant No. DE-FG03-95ER82099
Amount: $75,000

A major limitation on direct-fired turbines is the limited ability of current filter elements to survive long-term exposure to hot gas environments such as encountered in the pressurized fluidized bed combustor (PFBC) and the integrated gasification combined cycle (IGCC). In this Phase I project, a solution to this process limitation will be addressed by demonstrating the design, fabrication, and suitability of an advanced, low-cost silicon carbide (SiC) foam filter element for use in hot gas filtration of PFBC coal combustion products. The design is based on an SiC foam filter structure which serves to provide mechanical durability and support, and a bonded composite filter layer which provides filtration of nearly 100% of the fine particulates. The project will develop, characterize, design, and qualify (in Phase II) advanced, ceramic foam, hot gas filters as a lower cost, more durable replacement for current hot gas filter materials. Specifically, damage-tolerant open-cell SiC foam hot gas filters with porous composite filtration layers will be fabricated and evaluated for permeability, filtration efficiency, environmental degradation, and durability/damage tolerance. The end result of the project will be improved low-cost filters for use in PFBC (and IGCC) power generation systems showing increased durability and reliability compared to current filter systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful completion of the project will provide a solution to one of the primary obstacles to large-scale implementation of PFBC and IGCC power generation systems. New plant investment in these technologies is expected to reach $400 billion in the next several decades. The improved high-strength, low-cost filters will also find markets in ultrapure metal filtration, hot gas filters for automotive airbags, and for use in other highly corrosive environments.

ADVANCED FOSSIL FUELS RESEARCH

179

Use of Coal Fines for Production of Clean Fuel and Vapor-Grown Carbon Fiber--Applied Sciences, Inc., 141 West Xenia Avenue, P.O. Box 579, Cedarville, OH 45314-0579; (513) 766-2020
Mr. Robert L. Alig, Principal Investigator
Mr. Max L. Lake, Business Official
DOE Grant No. DE-FG02-95ER81926
Amount: $74,736

Millions of tons of raw coal fines are impounded annually in the U.S., representing a significant loss of potential low-cost fuel. Recovery of this low-cost fuel can be realized through a new industrial process capable of generating clean hydrocarbon fuel while simultaneously producing a commercially significant carbon fiber. This unique process uses hydrocarbons, metallic catalyst particles, and sulfur to produce very graphitic carbon fibers. Sulfur is added to enhance fiber growth and remains with the catalyst preventing the formation of sulfur dioxide in the effluent. Previous studies using high-sulfur coal have shown that coal is a viable carbon and sulfur source for the production of vapor-grown carbon fiber. Therefore, the pyrolytic conversion of coal fines into carbon fiber is offered as an inexpensive carbon and sulfur source for vapor-grown carbon fiber production while generating clean hydrocarbon fuel as a by-product. In Phase I, the feasibility of this concept will be determined by pyrolyzing pulverized coal fines in a reducing atmosphere at 2100°F. The exhaust will be analyzed using gas chromatography and mass spectroscopy in series, and the fiber produced will be characterized by scanning electron microscopy, x-ray analysis, apparent density, yield, and electrical conductivity.

Anticipated Results/Potential Commercial Applications as described by the awardee: The use of coal fines in the production of vapor-grown carbon fiber would significantly reduce material costs and generate a clean hydrocarbon fuel simultaneously.

180

An Innovative Pneumatic Transport Enhancer and Controller--Viscoustech, Inc., 5272 Butler Street, Pittsburgh, PA 15201-2600; (415) 782-6020
Mr. John Baker, Principal Investigator
Dr. C. Rajagopal, Business Official
DOE Grant No. DE-FG02-95ER82101
Amount: $74,794

A critical need exists for the improvement of the efficiency of solids handling systems. One of the common methods of transportation in solids transport is by use of pneumatic systems. Some of their primary advantages include being dust free, being subject to multiple uses of the same system, having low manpower costs, and ease of automation. The disadvantages are high power consumption, particle degradation and damage, and wear and abrasion of equipment. This project plans to alleviate these draw backs by developing an innovative and inexpensive industrial device which can control the amount of material flow in pneumatic transport by purging known amounts of gas from the system. This would lead to minimizing the energy requirements and particle degradation that are associated with pneumatic systems. The Phase I project will design, fabricate, and test the feasibility of the device in a horizontal and vertical pneumatic conveying system. The device can be incorporated into existing systems or be designed to form an integral part of new systems. In addition to its versatility, the device is easy to maintain. It will prove to be a cost effective method for enhancement and control of the flow of pneumatic systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The device developed in Phase I will increase the efficiency of pneumatic transport systems by reducing the power consumption and particle degradation. The device has the advantage of being inexpensive, easy to maintain since there are no moving parts, and suitable for fitting to any existing pneumatic system with minimum modifications. Considering the immense size of the particulate industry ($1 trillion), even a small improvement in the efficiency of pneumatic systems, such as minimizing the power consumption will greatly impact the industry as a whole.

IMPROVED TECHNOLOGY FOR OBTAINING RECYCLABLE MATERIAL FROM MUNICIPAL SOLID WASTE

181

Application of Raman Spectroscopy to Identification and Sorting of Post-Consumer Plastics for Recycling--National Recovery Technologies, Inc., 566 Mainstream Drive, Nashville, TN 37228-1223; (615) 734-6400
Dr. Edward J. Sommer, Jr, Principal Investigator
Dr. Charles E. Roos, Business Official
DOE Grant No. DE-FG02-95ER82038
Amount: $74,994

The handling of post-consumer plastic waste is an increasingly critical environmental, economic, and political issue. Plastics constitute only 9 percent by weight of municipal solid waste, but they occupy approximately one-fourth the volume of the waste stream. In order to sustain cost effective programs for plastic recycling, it is necessary for mixed plastics to be sorted according to chemical composition, since each plastic has its own chemical reprocessing pathway. Currently used automated technologies are very limited in ability to identify and sort plastics by polymer type. Manual sorting of waste plastics is expensive, prone to error, and can be unsafe. A new, cost-effective technology is urgently needed that can accurately identify and sort plastics by polymer type at high throughput rates. It is the objective of this project to develop such an automated plastics sorting technology. This will be done by combining materials sorting methods with Raman spectroscopic sensing to produce a high accuracy system for automated identification and sorting of waste plastics by polymer type. This device will read information encoded in the molecular structure of the plastics themselves to identify their chemical compositions and will use rapid high volume sorting techniques to sort them into product streams at commercially viable throughput rates. The feasibility data developed during Phase I will form the foundation for building and testing a pilot prototype sorter in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is expected that upon successful completion of Phase I and Phase II, application of the technology will significantly improve the economics of plastic recycling. The polymer sorting systems has potential commercial applications in recycling centers and secondary plastics processing facilities. Other applications are likely to be in process control in industrial settings for plastics and other materials where Raman scattering can provide rapid materials recognition. The Federal Government has many of the same waste handling problems as the private sector and it is expected that the technology can be used at Federal waste processing centers.

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Use of Computer Robotics to Reduce Human Contact with the Waste Stream and Lower the Costs for Recyclable Materials--National Recovery Technologies, Inc., 566 Mainstream Drive, Nashville, TN 37228-1223; (615) 734-6400
Dr. Charles E. Roos, Principal Investigator
Dr. Edward J. Sommer, Jr., Business Official
DOE Grant No. DE-FG02-95ER82037
Amount: $74,989

The handling and disposal of municipal solid waste (MSW) is a costly problem for virtually every community. The planned research will use computer simulation to investigate the feasibility of using robotics to increase worker efficiency and isolate workers from direct contact with MSW. Remote handling can significantly improve working conditions for material recovery facility (MRF) workers. Handsorting is expensive and it has high social and legal costs. MRF workers have high rates for workman's compensation, and these jobs have high rates of labor turnover and potential health problems. The extended use of remote handling equipment to reduce direct human contact with MSW is pivotal to safe, reliable and efficient treatment of MSW. Phase I will use computer simulation to measure the differences in sorting productivity. Selection from video images will be compared with typical handsorting rates at a MRF. Video tapes from MRF sorting lines at different facilities will be used for these tests. Phase I will measure the ergonomics of different selection techniques and computer algorithms. It will also determine the feasibility of using air jets and/or robotics to automate recovery of handsorted recyclable materials. The results will include preliminary estimates of the cost effectiveness of robotics to replace handsorting in an MRF.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of Phases I and II will increase both worker productivity and the amounts recycled, while reducing hazards to workers as they recover recyclable materials from all types of solid waste. Sorting workers will be moved into an office type environment isolated from the waste stream or commingled recyclables. This reduces requirements for both dust control and conveyor widths. The burden depths can be reduced since conveyor widths will no longer be limited by the distance workers can reach. The potential U.S. market is some 250 MRF facilities, which use handsorters to pick glass, paper and plastics.

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A Sensor for Automated Plastics Sorting--
Radiation Monitoring Devices, Inc., 44 Hunt Street,
Watertown, MA 02172-4624; (617) 926-1167
Dr. Michael Squillante, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-95ER82060
Amount: $75,000

Plastic materials have great potential for recycling because many plastics can be easily reprocessed into good quality material for new products. Most end users of the sorted plastics, however, require the plastic to be sorted by type and color. At the present time, many recycling plants rely on manual labor to observe and select plastics from a conveyor belt. This method suffers from a number of problems: high cost, exposure of employees to residual chemicals, poor efficacy for look-alike plastics (e.g. polyvinyl chloride and polyethyltetraphthalate), and subjective quality standards. The purity of the reclaimed material directly affects the resale value of the plastics. Automated methods already exist that can separate materials effectively and can reduce the impurity level to 50 ppm and the cost of materials by as much as 80%. No technology appears to be able to sort all types of plastics, but it should be possible to achieve this with two or three types of sensors. At the present time, x-ray fluorescence is one of the best methods for sorting polyvinyl chloride, but it is relatively expensive, is only useful for polyvinyl chloride, and is slower than most of the other methods that it would be combined with. A related technology based on electron backscattering would be equally effective for polyvinyl chloride, would achieve similar results on other materials, such as polystyrene and polyethylene, and should be significantly faster and less expensive because of reduced performance requirements on the detector. Phase I will examine the feasibility of applying electron backscattering technology to the problem of sorting common consumer plastics.

Anticipated Results/Potential Commercial Applications as described by the awardee: The market for this system is recycling equipment. This sensor technology should make plastic sorting less expensive and more effective. This would result in more automated systems being sold and used which would improve the quality of recycled plastic materials and reduce the cost of such material, making it more attractive for end users.

LIGHTWEIGHT COMPOSITE MATERIAL FOR AUTOMOTIVE STRUCTURES

184

Low-Cost Durable Tooling for High Production Rate Structural Reaction Injection Molding/Resin Transfer Molding Processing--
Metal Matrix Cast Composites, Inc., 101 Clematis Avenue, Waltham, MA 02154-7030; (617) 893-4449
Dr. James A. Cornie, Principal Investigator
Dr. James A. Cornie, Business Official
DOE Grant No. DE-FG02-95ER82024
Amount: $75,000

This project will develop mold tooling materials for use with structural reinforced injection molding (SRIM) and resin transfer molding (RIM). This new technology will enable greater flexibility, present opportunities for late stage design modification, and extend the economic advantages of SRIM and RIM. These innovative mold materials offer the following cost and productivity advantages: (1) machined molds for processing composites will be completely replaced; (2) tooling for components with limited-to-high volume production runs will be made possible at low cost (which will also permit effective scaleup for high volume automotive mass production, utilizing identical tooling process parameters); (3) the cost of making prototype new and experimental components will be greatly reduced; and (4) high volume manufacturing processes will use identical tooling to make prototype molds, hence, processing and properties will be identical. The Phase I effort will: (1) investigate methods for producing high definition, high surface finish, moldable casting tools; (2) optimize the process and enhancement of the material surface through additions designed to toughen mold edges; (3) develop a highly robust plating system that will maximize tool life; (4) estimate tool life by examining tool and part surfaces after repetitive uses; (5) demonstrate technology on a sub-scale application; and (6) develop cost models for this and competitive processes.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is expected that this tooling concept should be considerably cheaper than present state-of-the-art technology. It should be ideal for casting new composite materials, for the selection and forming of composite preforms, for fixturing preforms and finished parts for precision trimming, for rapid making of prototype parts, and for commercial transportation and military applications with limited production runs.

HYBRID ELECTRIC VEHICLE TECHNOLOGY

185

High Power Switching Controls for Hybrid Electric Vehicle Transportation Systems--
Advanced Technology Materials, Inc., 7 Commerce Drive, Danbury, CT 06810-4169; (203) 794-1100
Mr. Michael A. Tischler, Principal Investigator
Mr. Daniel P. Sharkey, Business Official
DOE Grant No. DE-FG02-95ER81914
Amount: $75,000

Hybrid, all-electric, and internal combustion vehicles will require more and more sophisticated electronics and sensors. Vehicular electronics must be able to operate over wide temperature ranges and in corrosive atmospheres. For very high voltage and high power operation, devices such as vertical metal oxide semiconductor field effect transistors (MOSFETs) and insulated gate bipolar junction transistors (IGBTs) do not exist in silicon (Si) because of the limitation in breakdown field strength. Because of its unique properties, silicon carbide (SiC) is an ideal semiconductor for both high temperature and high power applications. In comparison with silicon and gallium arsenide, SiC has a larger bandgap (>2.5 times), thermal conductivity (>3 times) and breakdown field (>10 times). These characteristics permit SiC devices to operate in high temperature and harsh environments and provide the cost, weight, and efficiency savings required to make commercially viable hybrid and electric vehicles. This Phase I project will examine a unique oxidation process that offers the potential to passivate defects present in the substrate, such as micropipes, and permits fabrication of large area, high integrity oxides. In Phase II, SiC vertical power MOSFETs will be designed and fabricated using these high integrity, device-quality oxides.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned technology development project will lead to the fabrication of high power, high temperature transistors. These devices have a wide range of applications ranging from hybrid automobiles, aeronautics, and industrial power generation and control.

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A Semiconductor Oxygen Sensor for Hybrid Electric Vehicle Control--Creare, Inc., P.O. Box 71, Etna Road, Hanover, NH 03755-0071; (603) 643-3800
Dr. Robert Kline Schoder, Principal Investigator
Dr. James A. Block, Business Official
DOE Grant No. DE-FG02-95ER81946
Amount: $74,367

Oxygen sensors that are currently standard equipment on production automobiles are highly nonlinear (essentially digital). As a consequence of this nonlinearity, computationally intensive engine models and special filters are required to obtain useful feedback data from these sensors for engine control. Hybrid electric vehicles have unique control and sensing requirements. The use of nonstandard secondary power sources possibly utilizing alternative fuels will require oxygen sensors with improved characteristics for hybrid vehicle control. This project will develop a thin film, metal oxide, semiconductor oxygen sensor that is fabricated using physical vapor deposition (PVD). The advantages of PVD are that it allows the control of the critical thin film characteristics that determine sensor performance and that it is a common mass production process. The oxygen sensor promises to be more linear, more sensitive, more robust and less expensive to manufacture than similar, presently available devices. In Phase I, the feasibility of this concept will be assessed by designing, fabricating, and testing the key element of the oxygen sensor. In Phase II, the sensor design will be refined, the sensing element will be fabricated, the sensor will be packaged appropriately, and the complete unit will be field tested.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will develop a linear oxygen sensor fabricated using a technique amenable to mass production. It is expected that the oxygen sensor will have wide commercial application in the control of hybrid electric vehicles, standard internal combustion engine driven vehicles, advanced life support systems, and detection of emissions from combustion-based industrial processes.

187

A Novel Combustion Sensor for Hybrid Vehicles--Physical Optics Corporation, 20600 Gramercy Place, Suite 103, Torrance, CA 90501-1821; (310) 320-3088
Dr. Roy Clark, Principal Investigator
Ms. Patty Shaw, Business Official
DOE Grant No. DE-FG03-95ER82050
Amount: $74,990

The objective of this project is to design and evaluate a compact, rugged combustion sensor for hybrid vehicle applications. The device is based upon a Fabry-Perot interferometer in which the free spectral range is set to the rotational line spacing of the molecular gas of interest. Phase I will provide a complete system design suitable for Phase II development into a prototype sensor for hybrid vehicle implementation.

Anticipated Results/Potential Commercial Applications as described by the awardee: In addition to supporting hybrid vehicle development, this project will also result in the development of small, sensitive gas monitoring products. These will have wide-ranging applications in industrial process control, combustion and environmental monitoring, and anesthesiology.

188

A Real Time Combustion Sensor for Hybrid Electric Vehicles--Southwest Sciences, Inc., 1570 Pacheco Street, Suite E-11, Santa Fe, NM 87505-3987; (505) 984-1322
Dr. Daniel B. Oh, Principal Investigator
Dr. Alan C. Stanton, Business Official
DOE Grant No. DE-FG03-95ER82072
Amount: $75,000

Sensors for on-line monitoring of hybrid electric vehicle exhaust are needed for optimizing engine combustion efficiency while keeping emissions of pollutants under Government limits. This project will develop a fiber optic/diode laser-based sensor for measurement of key exhaust species. This sensor will be highly sensitive and selective to the targeted species, provide a rapid response (under 10 Hz), be operational in a rugged environment, have low power requirements, and be inexpensive. The essential technique which will be employed to achieve these goals is known as wavelength modulation spectroscopy (WMS). In the past, field sensors have been developed which use WMS for detecting trace gas species (including pollutants). These sensors have been demonstrated to be capable of unmanned operation for a period of several months. In Phase I, the key exhaust species which will be monitored from a small 4-stroke engine will be carbon monoxide (CO) and carbon dioxide (CO_2). These species will be measured using one diode laser with expected sensitivities of 60 ppm for CO and 600 ppm for CO_2. The CO/CO_2 ratio is an indicator of combustion efficiency and will be correlated with the air/fuel ratio. In Phase II, the sensitivity for these species can potentially be increased twenty-fold. The Phase I results will be valuable in developing a Phase II diode laser-based sensor design for on-board engine monitoring and will be helpful in establishing the sensitivity which can be achieved for detecting other species such as nitric oxide, formaldehye, methane, and acetylene.

Anticipated Results/Potential Commercial Applications as described by the awardee: The direct result of this research will be a diode laser sensor for key species in the exhaust of hybrid electric vehicles. Thus, this sensor will be useful to development of future vehicle technology in the automobile industry. The technology used for this project is also applicable to environmental monitoring and combustion research.

MODULAR AND PANELIZED PASSIVE SOLAR BUILDINGS

189

Design of Townhouses for Inner City or Urban Infill Sites Using Steel-Framed, Passive-Solar Mega-Modules--Steven Winter Associates, Inc., 50 Washington Street, Norwalk, CT 06854-2710; (203) 852-0110
Mr. Steven Winter, Principal Investigator
Ms. Marie Costello-Starnes, Business Official
DOE Grant No. DE-FG02-95ER82077
Amount: $75,000

This project will integrate architectural/engineering design, passive-solar and energy efficiency strategies, and steel-framed modular production technologies to develop a variable family of townhouses that can be adapted to different urban infill sites. The housing units will target low to moderate income New York City homeowners, and will be suitable for replication in inner-city neighborhoods throughout the United States. Phase I work will result in the design of prototypical townhouse modules, together with analyses to verify their efficiency and cost-effectiveness. Final documentation will be suitable for Phase II prototype construction, testing and commercialization.

Anticipated Results/Potential Commercial Applications as described by the awardee: If the project is successful a family of innovative passive-solar modular townhouses will have been designed and analyzed to verify performance characteristics. Commercialization of the system of townhouses will focus on the 145,000 infill sites in New York City potentially available for new housing construction. Designs and strategies developed in this research will be made available to other design/production teams around the country to address infill housing

opportunities in inner-city neighborhoods in major cities throughout the United States.

TECHNICAL IMPROVEMENTS FOR ADVANCING PHOTOVOLTAIC APPLICATIONS

190

A Low Cost Receiver Plate Manufacturing Process for High Concentration Photovoltaic Systems--Amonix, Inc., 3425 Fujita Street, Torrance, CA 90505-4018; (310) 325-8091
Mr. Gerald Turner, Principal Investigator
Mr. Vahan Garboushian, Business Official
DOE Grant No. DE-FG03-95ER81921
Amount: $60,000

This project will develop a high concentration receiver plate manufacturing process that will reduce production costs and have sufficient volume throughput to sustain multi-megawatt system deployment rates. The present standard receiver plate consists of a 30" X 40" aluminum sheet that is bonded to a copper circuit with a dielectric barrier. The copper circuit must be precisely located and etched to provide registration for the high-concentration solar cells, secondary optical elements, and circuit interconnects. The existing process, which uses laminar presses and chemical etch techniques, is costly and labor intensive. Phase I activities include stamping, rolling, and autoclave lamination.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will result in a receiver plate manufacturing process that will significantly lower production costs and enable market entry for large scale photovoltaic electrical power generation in high concentration systems.

191

Slicing of Silicon Ingots with Reduced Kerf-- Crystal Systems, Inc., Shetland Industrial Park, 27 Congress Street, Salem, MA 01970-5575; (508) 745-0088
Mr. Mayard B. Smith, Principal Investigator
Dr. Chandra P. Khattak, Business Official
DOE Grant No. DE-FG02-95ER81949
Amount: $75,000

It is recognized by the photovoltaic industry that crystalline silicon produced in an ingot form and sliced into wafers is the only near-term choice for manufacturing modules. Slicing techniques utilized in production today have large kerf loss and/or high consumable costs which make the slicing cost more than one half the wafer cost. Therefore, slicing of crystalline silicon ingots is considered to be the major obstacle for producing low-cost photovoltaic modules, since wafering is a substantial portion of the total cost of wafer production. This project will use the Fixed Abrasive Slicing Technique (FAST), combined with a newly developed shaped wire, for significantly reduced kerf and more effective slicing. The feasibility of using shaped-wire FAST to slice silicon with improved material utilization will be demonstrated during Phase I. The current practice uses about 14 g of silicon per 10 cm x 10 cm wafer. The shaped-wire FAST has the potential of using about seven to eight g/wafer -- a reduction of 50% in silicon usage per wafer. Once the shaped-wire FAST approach is established, it can be combined with existing developments (e.g., high throughput, double-headed FAST slicer, bladepack preparations) so that this new technology can be adopted quickly by the photovoltaic industry. FAST uses diamond as an abrasive and water as a coolant; therefore, no hazardous waste is generated.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful implementation of this project will produce twice as many solar cells as compared to the current practice This will allow the photovoltaic industry to build future modules using over 50 years of experience of the multi-billion dollar semiconductor industry.

192

A Novel Method to Recycle Thin Film Semiconductor Materials--Drinkard Metalox, Inc., 2226 North Davidson Street, Charlotte, NC 28205-1830; (704) 332-8173
Dr. Robert Goozner, Principal Investigator
Mr. Fred Gallagher, Business Official
DOE Grant No. DE-FG02-95ER81951
Amount: $75,000

An important problem in the field of photovoltaic (PV) technology is that there is currently no effective process to remove and recycle the semiconductor materials in an environmentally benign fashion. The metals which can be present in thin film PV devices may include cadmium, copper, gallium, indium, selenium, and tellurium. They must be separated from are glass, plastic, or similar low cost substrates. Hydrometallurgical solvent systems have been developed which have been demonstrated to be very effective in solubilizing metals. This solvent will be highly effective in leaching the semiconductor metals in PV wastes from their substrates. The advantages of this process include the thoroughness of the metals dissolution and the proven ability to achieve 100% reclamation and recycling of the solvent. The recovered metals will be suitable for sale to metal refiners. Other than well-cleaned glass or similar substrate exiting from the process, there will be no solid, liquid, or gaseous waste streams. If there is any residual leaching solvent on the exiting substrates, it can be easily and quantitatively removed, collected, and reused by drying. The resulting substrate will be free of metals and will be suitable for conventional recycling. Phase I will demonstrate: (1) the process on the laboratory bench using representative samples of PV materials, (2) that the substrate material leaving the process is free of contaminants and satisfies Environmental Protection Agency Toxicity Characteristic Leaching Procedures, and (3) that mixed metal oxides can be produced with 100% recycle of the solvent for the entire process. The suitability for recycling of the metal oxides to PV module manufacturers, or for selling them to established metallurgical refineries, will be evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: The goal is to develop a commercialized technology to recycle or reclaim PV semiconductor waste. A centralized processing facility will be established which will profitably reprocess PV manufacturing waste and spent PV cells into metal oxide chemicals either for sale or for reuse by PV cell manufacturers.

193

A Low-Cost, High-Yield Technique to Produce 100 Micron Thick Photovoltaic Wafers--Evergreen Solar, Inc., 49 Jones Road, Waltham, MA 02154-1645; (617) 736-1744
Mr. Robert C. Folweiler, Principal Investigator
Mr. Richard G. Chleboski, Business Official
DOE Grant No. DE-FG02-95ER81969
Amount: $75,000

Advances are needed for manufacturing low cost, thin (less than 300 micron), crystalline silicon wafers for photovoltaic applications. This project will develop a method of producing silicon ribbon in a continuous fashion. The method is capable of producing extremely thin ribbon for solar cells. To date, however, the thin ribbon grown with this technique has been too narrow and/or has had too much residual stress to be practical for high volume solar cell manufacturing. Growing wider (approximately two inches) thin ribbon requires managing the stress which is induced when the ribbon is cooled from the melting point of silicon to room temperature. Phase I will construct a novel afterheater to control the ribbon's cooling profile, and test it by growing thin (less than 300 micron), wide (greater than two inches in width) silicon ribbon. This afterheater will be designed to facilitate a rapid changeover from one cooling profile to another and will therefore provide an excellent experimental vehicle for the control of the ribbon's stress, buckling, and quality. The afterheater's design will be guided by a simplified analytical approach to the thermomechanical problem of calculating the desired thermal profile. Modeling and empirical feedback from the growth of thin ribbon will be used in an iterative fashion to optimize the cooling profile.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project has the potential to produce 100 micron thick, flat, low stress silicon wafers for photovoltaic applications. This would reduce the consumption of silicon by at least a factor of five over conventional ingot wafer technologies and eliminate wafer sawing and etching costs. Combined, these savings would reduce wafer costs by approximately 80% to 90% over conventional ingot technologies. When successfully deployed, this will be a significant contributor towards the goal of widespread commercialization of photovoltaic electricity generation.

194

Advanced Wire Saw Technology for Photovoltaic Wafers--GT Equipment Technologies, Inc., 472 Amherst Street, Nashua, NH 03063-1204; (603) 883-5200
Mr. Jonathan A. Talbott, Principal Investigator
Dr. Kedar P. Gupta, Business Official
DOE Grant No. DE-FG02-95ER81978
Amount: $74,909

Inexpensive silicon wafers are critical to the widespread use of photovoltaics. A high yield, efficient process is required for slicing crystalline and polycrystalline ingots of silicon, germanium and III-V compound crystals, with minimum material losses and better surface finish. The wire saw can meet these demands and is considered to be a better technology than the current inner diameter (ID) saw that slices one wafer at a time. The wire saw has a potential of cutting much thinner wafers from larger ingots at a faster rate. Since the effect of process parameters on wire slicing is not well understood, Phase I efforts will be devoted first to developing a model that can account for the stress in a moving wire after initial axial tensions, the effect of tangential and radial loads, resonant frequencies of the wire, material removal by abrasive action, and heat removal by the slurry flow. A computer algorithm will be developed to perform the analysis, and experiments will be conducted to validate the model. These results, together with a critical review of existing technologies, will be used to develop preliminary specifications for an advanced wire saw.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will ultimately develop advanced wire saw technology for high throughput of silicon and other crystalline and polycrystalline ingots to directly improve the end product (wafer) price and availability. This will give an edge to the United States technology in an area that is dominated by foreign companies and will make photovoltaics cheaper.

195

In-Situ Removal and Recycling of Copper Indium Selenide from Thin-Film Solar Cells--Interphases Research, 722 Rushing Creek Place, Thousand Oaks, CA 91360-2665; (805) 492-9814
Dr. Shalini Menezes, Principal Investigator
Mr. Leslie Affonso, Business Official
DOE Grant No. DE-FG03-95ER82002
Amount: $75,000

The optimum photovoltaic (PV) properties of $CuInSe_2$ have been successfully utilized in the Mo/p-$CuInSe_2$/n-CdS/ZnO (molybdenum/p-copper indium selenide/n-cadmium sulfide/zinc oxide) thin film cell with solar conversion efficiencies exceeding 16%. Two serious impediments for the large scale $CuInSe_2$ module deployment are the low raw material (In) reserves and heavy metal (Cd, Se) waste disposal regulations. Since PV modules contain only a small fraction of metals relative to the large (glass) bulk stream, conventional heavy metal recycling methods would be impractical and wasteful. This project will develop an environmentally responsible, closed-loop, low cost method, specifically tailored to recycle the $CuInSe_2$ thin film PV cells. Phase I will determine method feasibility and identify process parameters for maximum recycling efficiency, minimum environmental impacts. Phase II will extend the process to the other cell components: CdS window, $CuInSe_2$/CdS bilayer, front ohmic contact.

Anticipated Results/Potential Commercial Applications as described by the awardee: The end product of the proposed research will be a $CuInSe_2$-module recycling process with special advantages, including: low cost, nearly complete removal and recycling of the semiconductor material, no unwanted waste streams, nondestructive rapid processing, amenability to scale-up. Availability of this process will ensure the commercial success of the $CuInSe_2$ PV industry and offer economic and environmental benefits to the utilities and various government sectors.

196

A Large Area Solar Simulator for Uniform and Continuous Illumination--Physical Sciences Inc., 20 New England Business Center, Andover, MA 01810-1077; (508) 689-0003
Dr. Alfred Ducharme, Principal Investigator
Mr. George E. Caledonia, Business Official
DOE Grant No. DE-FG02-95ER82052
Amount: $74,968

This project will develop a continuous flux solar simulator for application in testing and evaluation of large area photovoltaic cells. Uniform illumination over 1 m^2 will be achieved using a lightweight and compact integrating sphere. The output for multiple xenon arc lamps will be spectrally-filtered to match the solar spectrum and coupled to the sphere using unique fiber optic technology. This approach allows remote siting and articulation of the integrating sphere. The output from the integrating sphere will be transferred to the test plane using an inverted compound parabolic concentrator that will be mounted directly onto the exit port of the sphere. Variable fluxes may be achieved around the nominal solar constant by adjusting the distance between the sphere and target plane. In Phase I, a sub-scale prototype will be designed and fabricated in order to verify the uniformity of illumination, flux level per unit xenon lamp input power, and the spectral matching to the solar spectrum. This testing will establish the feasibility of the approach by evaluating each subcomponent. The test data will be used, in conjunction with a commercial optical instrument manufacturer and partner, to design a full-scale simulator to be developed, tested and delivered in the Phase II portion of the project.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will develop and deliver a lightweight, compact solar simulator with high continuous flux and large area illumination capability. No such simulator is currently available. Working together with a major supplier of smaller scale simulators, a commercial version will be produced that is expected to address needs in photovoltaic testing, sensor calibration, and materials testing.

197

A Large-Area Air Mass 1.5 Non-Pulsed Solar Simulator for Testing Photovoltaic Modules: An Experimental Design--SC-International Inc., 346 West Pine Valley Drive, Phoenix, AZ 85023-5266; (602) 993-7877
Mr. Gene A. Zerlaut, Principal Investigator
Mr. Gene A. Zerlaut, Business Official
DOE Grant No. DE-FG03-95ER82064
Amount: $74,976

This experimental project has the objective of developing the design parameters necessary to construct a metal halide, multi-lamp solar simulator for determining current-voltage characteristics and for performance testing of a wide range of photovoltaic modules. Phase I will develop a lamp array, optimized in terms of its spectral irradiance distribution, uniformity of irradiance in the target plane, and cost. High intensity discharge lamps will be powered using both regulated lag and reactor ballasts. The trade-offs in using one versus the other will be determined with respect to irradiance control and spatial uniformity in the target plane. Irradiance in the target plane will be measured by using a multi-radiometer walking beam flux mapper and a unit-cell array of seven lamps arranged in a hexagonal close-pack configuration (which would be the repeating unit in a large multi-lamp array). The target plane irradiance maps generated for various lamp array designs will be used as input data for a computer simulation of a large array. This will be used in turn to prepare design and performance specifications for a Phase II project.

Anticipated Results/Potential Commercial Applications as described by the awardee: A simulator design which offers reasonably straightforward construction, provides adequately uniform irradiance in the target plane, and is reasonable in cost, would be useful for solar simulation to support the testing of photovoltaic modules. Other applications include solar hot water collectors, automotive subassemblies, building materials and components, and modular structures used out-of-doors which subjects them to thermal stresses during their useful life.

198

Environmentally Responsible Recycling of Thin-Film Cadmium Telluride Modules--Solar Cells, Inc., 1702 North Westwood, Toledo, OH 43607-1241; (419) 534-3377
Dr. Richard A. Sasala, Principal Investigator
Mr. Frederick L. Yocum, Business Official
DOE Grant No. DE-FG02-95ER82068
Amount: $75,000

There is a great potential for photovoltaic (PV) power cost reduction through the development of polycrystalline thin-film modules. Furthermore, there is evidence that cadmium telluride (CdTe) solar cells will be the technology to open vast new markets for PV energy conversion. One aspect that must be addressed, however, is the environmental implications of Cd in the modules at the end of the module life. A cost-effective technique to recover Cd and Te from the modules in an economical, reliable, scaleable, and environmentally benign manner is the project emphasis for Phase I. The technique developed will address environmental concerns involving the final disposition of the product. For the planned technique, modules will be exposed to a succession of mechanical, chemical, and/or thermal treatments in order to (1) delaminate the modules, (2) strip the semiconductors, and (3) refine byproducts. The work will address safety and health issues and will attempt to minimize unwanted byproducts. The technologies to be evaluated for Cd and Te recovery include precipitation, electrolytic recovery, ultrafiltration, and ion exchange. It is expected that the resultant glass will be acceptable to a standard glass recycle and that the Cd and Te will have at least nominal value to a materials supplier for further refinement and ultimate reuse.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful completion of this research will enable cost and environmentally effective recycling of CdTe modules at the end of their useful life. This will address market concerns of primarily adverse environmental issues caused by the presence of Cd. With the technology intact for "cradle-to-cradle" control of Cd and the tremendous low cost, high throughput potential of CdTe, the future becomes bright for CdTe based PV and for renewable electric power for the world with minimal adverse environmental effects.

199

A Non-Tracking, Low-Cost Photovoltaic Concentrator Array--Solar Engineering Applications Corporation, 3500 Thomas Road, Suite E, Santa Clara, CA 95054-2049; (408) 986-9231
Mr. Neil Kaminar, Principal Investigator
Mr. Don Curchod, Business Official
DOE Grant No. DE-FG03-95ER82069
Amount: $74,972

A large U.S. export market exists for photovoltaic (PV) systems for remote applications. Significant price reductions will serve to expand this market and open others. The majority of the existing remote market is for 30 W to 300 W panels. Solar cells remain the major cost component for PV modules. Thin-film cells are potentially low cost, but technical problems remain that may never be solved. Traditional concentrator technology shows promise but only for larger systems. The workhorse of PV cells remains one-sun crystalline silicon. One-sun crystalline silicon cells can be easily pushed to two suns concentration without any changes in the cells. This project will develop a 2:1, non-tracking concentrator that uses standard one-sun crystalline silicon cells. This module can be fixed on roof tops or other support structures. The module will be very economical to produce, ship, and install. It can immediately reduce the cost of PV modules to less than half. It can also immediately double the production capacity of cell manufacturers without any capital investment. In Phase I, the design of the module will be completed and a proof-of-concept sample will be produced. The module will be ready for pilot production in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The PV market has been forecast to be a trillion dollar market, once the price reaches approximately half the present price. Over half of this market is U.S. export. The work planned here will provide an immediate path to realize this potential.

APPENDIX A

Alphabetical List of Awardees

3D-Computing ***74***
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(214) 341-0000

A. J. Boggs & Company ***46***
Mr. James D. Anderson, Business Official
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AbTech Corporation ***134***
Mr. Gerard J. Montgomery, Business Official
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Aculight Corporation ***135***
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ADA Technologies, Inc. ***145***
Dr. Michael D. Durham, Business Official
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Adelphi Technology, Inc. ***38***
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Advanced Ceramics Research, Inc. ***111***
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(602) 792-2616

Advanced Processing Technologies, Inc. ***126***
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Advanced Refractory Technologies, Inc. ***168***
Mr. Keith A. Blakely, Business Official
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Buffalo, NY 14207-2341
(716) 875-4091

Advanced Technology Materials, Inc. ***36, 185***
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Aerodyne Research, Inc. ***49***
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American Research Corporation of Virginia ***113***
Mrs. Anne Churchill, Business Official
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References denote award numbers

American Superconductor Corporation ***25, 26, 27, 28***
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Amonix, Inc. ***190***
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Analysis Consultants ***20***
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ApoCom, Inc. ***47***
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Aspen Systems, Inc. ***1***
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Astralux, Inc. ***85***
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AstroPower, Inc. ***136***
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Atlas Technologies, Inc. ***86***
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Bend Research, Inc. ***151, 152***
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BIODE, Inc. ***45***
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Boston Physics ***105***
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Boulder Metric ***106***
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Busek Company, Inc. ***169***
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***Calabazas Creek Research** 89, 90*
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***Compact Membrane Systems, Inc.** 21*
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***Consultec Scientific, Inc.** 22*
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***Context Productions** 53*
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***Cordec Corporation** 2*
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***Creare, Inc.** 116, 186*
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***Crystal Associates, Inc.** 137*
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***Drinkard Metalox, Inc.** 127, 192*
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***Duly Research, Inc.** 57*
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Dynamics Technology, Inc. ***141***
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E. R. Johnson Associates, Inc. ***33***
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APPENDIX B

State Listing of Awardees

Arizona	9, 111, 115, 165, 197
California	4, 5, 18, 19, 20, 38, 39, 43, 48, 53, 57, 61, 62, 63, 66, 67, 72, 83, 89, 90, 91, 100, 104, 107, 110, 118, 119, 121, 130, 138, 141, 142, 144, 146, 154, 171, 178, 187, 190, 195, 199
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References denote award numbers

APPENDIX C

Grant Application Submissions and Awards Listed by States, Territories, and Possessions

State	Number Submitted	Number Selected
Alabama	15	0
Arizona	46	5
Arkansas	11	0
California	258	41
Colorado	89	12
Connecticut	61	13
Delaware	14	3
Florida	28	2
Georgia	8	0
Idaho	1	0
Illinois	32	5
Indiana	4	0
Iowa	2	0
Kansas	6	0
Kentucky	6	2
Louisiana	30	1
Maine	7	2
Maryland	50	2
Massachusetts	195	34
Michigan	32	3
Minnesota	13	1
Mississippi	6	0
Missouri	7	1
Montana	3	0
Nevada	3	0
New Hampshire	23	4
New Jersey	46	5
New Mexico	44	2
New York	65	10
North Carolina	24	5
North Dakota	4	0
Ohio	70	3
Oklahoma	8	0
Oregon	19	3
Pennsylvania	41	3
Rhode Island	6	0
South Carolina	3	0
South Dakota	3	0
Tennessee	38	9
Texas	64	7
Utah	39	7
Vermont	3	0
Virginia	82	7
Washington	41	7
West Virginia	3	0
Wisconsin	9	0
Wyoming	6	0
Non-U.S.*	1	0

Although eligible to participate, there were no submissions from Alaska, the District of Columbia, Hawaii, Nebraska, Puerto Rico, the Virgin Islands, the Commonwealth of the Northern Mariana Islands, or the Trust Territory of the Pacific Islands.

*Ineligible to participate since the applicant was not a U.S. firm with its primary place of business in the U.S as required by Section 2.3 of the 1995 program solicitation.

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SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM
(PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0598)

U.S. DEPARTMENT OF ENERGY
GERMANTOWN, MD 20874
JULY 10, 1995

SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0598)

As a former chairman of the SBIR Application Score Verification Panel that had been appointed to evaluate Phase II grant applications for the SBIR program, I am familiar with the Panel's evaluation procedures and its methodology. I believe that the Panel has proceeded in accordance with applicable laws and regulations, that the evaluation was thorough and equitable, and that the information presented formed a sound basis for selection. This statement describes the procurement and sets forth my selection decision.

Procurement Description

The Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564), requires that each Federal agency with an extramural research or research and development budget exceeding $100 million establish an SBIR program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies over the 18 years of the program are as follows:

Fiscal Year	SBIR Set Aside (%)
1983	0.2
1984	0.6
1985	1.0
1986-1992	1.25
1993-1994	1.5
1995-1996	2.0
1997-2000	2.5

Public Law 97-219 also prescribes that the SBIR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the SBIR program. This phase will have a period of performance which is typically six months in duration. Awards during this phase will be up to $75,000. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $750,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-SBIR funded Federal contracts for products or services intended for use by the U.S. Government.

On November 15, 1993, the Department of Energy (DOE) issued its twelfth annual program solicitation for Phase I SBIR grant applications. We received 2276 applications in response to that solicitation; and on June 10, 1994, we selected 216 applications for Phase I funding, of which 212 proceeded to grants on August 15, 1994.

The Phase II SBIR program competition is limited to successful Phase I awardees. Under DOE procedures, grant applications for Phase II could be submitted at any time when it was deemed that sufficient progress had been attained under Phase I to justify the effort to be proposed for further development under Phase II. Applicants who wanted to maintain project funding continuity from Phase I to Phase II were asked by DOE to submit their applications not later than January 17, 1995, whereas the submission deadline for proposers not seeking to preserve project continuity was April 24, 1995. Based on the 212 Phase I awards, 45 Phase II applications were submitted by the January 17, 1995, deadline. From this submission, 17 were selected for Phase II awards in March 1995.

This current selection is made from applicants not seeking to preserve project continuity and from those applications that were received by January 17, 1995, but not yet funded. Of the group, 147 were received by the April 24, 1995, deadline, and 28 were not funded from the earlier submissions, for a total of 175 applications eligible for funding at this time.

Selection Criteria

Selections for Phase II awards were made on scientific and technical merit and commercial potential based upon the criteria listed below. Criterion 1 is given twice the weight of each of the other criteria. The six criteria are as follows:

1. The scientific/technical quality of the proposed research or R&D with special emphasis on its degree of innovation.

2. The qualifications of the Principal Investigator and other key personnel to carry out the proposed work and the level of adequacy of available or obtainable instrumentation and facilities.

3. The anticipated benefits, technical and/or economic, of the proposed research, with special emphasis on the likelihood that the project will attract further funding for product or process development after the SBIR support expires.

4. The degree to which the Phase I objectives were met at the time of Phase II grant application submission.

5. The soundness and level of adequacy of the Phase II proposed work plan to meet the problem or opportunity.

6. The commercial potential of the proposed research or R&D as evidenced by (a) the small business concern's record of commercializing SBIR or other research, (b) the existence of Phase II funding commitments from private sector or non-SBIR funding sources, (c) the existence of Phase III follow-on funding

commitments for the subject of the research, and (d) the presence of other indicators of commercial potential of the idea.

Criteria 1 through 5 ensure that award decisions will be based primarily on scientific and technical merit. Criterion 6 on commercial potential was added in 1994 to conform to the requirements of P.L. 102-564.

In all applications selected for awards, it was demonstrated that a minimum of one-half of the funded research or analytical effort would be performed by the applicant organization.

Selection Rationale

A Technical Project Manager (TPM) was appointed for each of the Phase I projects resulting from successful Phase I applications. Expert reviewers including DOE Laboratory personnel, university professors, and private industry personnel were selected with the help of the TPM, and they evaluated applications against criteria 1 through 5 and 6d. The TPM then scored applications based on these reviews. An SBIR Application Score Verification Panel, consisting of DOE staff and other technical personnel, was established to ensure relative uniformity of scoring across the board for these criteria and to assure that scores were based predominantly on meaningful technical reviews. The Panel was also chartered to ensure that there was consistency of scoring both within and between topics.

Criteria 6a, 6b, and 6c were evaluated by Panel members based on (non-technical) information provided in the grant applications, and a score was assigned for each of these criteria. The scores for 6a, 6b, 6c, and 6d were combined, with equal weight for each, to arrive at a single score for criterion 6. Then each application was assigned a total score based on the weighting described in the beginning of the previous section. Finally, the Panel ranked the 175 applications in order of their total scores.

I have looked at the evaluation documentation presented by the TPMs. I have also carefully reviewed the recommendations of the SBIR Application Score Verification Panel and have agreed that the evaluations of the reviewers, the scoring of the TPMs, and the recommendations of the Panel provided valid bases upon which to make a selection. Therefore, based on the ranking of the Panel, I have selected 64 applications for negotiation for award. This brings the total number of Phase II applications selected for negotiation to 81 including the 17 selections made in March 1995. Included in the 81 applications are all those which were within two points of the highest possible total score. The remainder was selected from among applications that were rated three points below the highest possible total score on the basis of program balance. It is my view that these applications represent outstanding technical quality and attest to the commitment of the SBIR program to excellence and to the development of high technology in the small business sector.

Samuel J. Barish

Samuel J. Barish
SBIR Program Manager
Date: 7/10/95

Attachments:
Appendix A: Listing of applications selected for negotiation for award.
Appendix B: Project summary of each application.

APPENDIX A

DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1995 PHASE II AWARDS

Company	Project Title
Abacus Controls, Inc. P.O. Box 893 Somerville, NJ 08876-0893	A Trimode Power Processor to Optimize Photovoltaic, Battery, and Diesel-Generator Sources for Economic Stand-Alone Power Plants
Acrion Technologies, Inc. 9099 Bank Street Cleveland, OH 44125-3436	Landfill Gas Conversion to a Contaminant-Free Methane-Carbon Dioxide Reformer Feedstock for Methanol Synthesis
Advanced Fuel Research, Inc. 87 Church Street P.O. Box 380379 East Hartford, CT 06138-0379	X-Ray Absorption Spectroscopy for Trace Analysis of Chemical Phase and Composition
Advanced Modular Power Systems, Inc. 4667 Freedom Drive Ann Arbor, MI 48108-9784	A Low Emission Alkali Metal Thermal to Electric Converter (AMTEC) Automotive Power System
Advanced Photonix, Inc. 1240 Avenida Acaso Camarillo, CA 93012-8754	Reliable Large-Area Avalanche Photodiodes (APDs) for Improved Calorimetry
AeroVironment, Inc. 222 East Huntington Drive Monrovia, CA 91016-3500	A Look-Ahead Adaptive Control System (LACS) for Wind Turbine Generators
Aerodyne Research, Inc. 45 Manning Road Billerica, MA 01821-3976	An Agile, Tunable Mid-Infrared Source (7-14 microns) Utilizing Room Temperature Near Infrared Diode Lasers for Measuring Atmospheric Trace Species
Aerometrics, Inc. 550 Del Rey Avenue, Unit A Sunnyvale, CA 94086-3528	An Optical Technique for Non-Intrusive Characterization of Fine Particulates in Flue Gas Streams
Amparo Corporation P.O. Box 2687 Santa Fe, NM 87504-2687	A High Power Solid State Amplifier
Anatole J. Sipin Company, Inc. 505 Eighth Avenue New York, NY 10018-6505	A Programmable Particulate Sampling System

*Project provided with funding continuity following application submission by January 17, 1995

Andcare, Inc. 2810 Meridian Parkway Suite 152 Durham, NC 27713-2277	An Advanced Electrochemical Sensor for the Simultaneous Analytical Measurement of Three Chemical Species
Apfel Enterprises, Inc. 25 Science Park Suite 676 New Haven, CT 06511-1968	Plutonium Assay Using Superheated Drop Technology in Support of International Atomic Energy Agency Safeguards
Aspen Systems, Inc. 184 Cedar Hill Street Marlborough, MA 01752-3017	Modular/Transportable Classroom Structures
BIODE, Inc. 2 Oakwood Road Cape Elizabeth, ME 04107-2025	An Acoustic Plate Mode Sensor for Aqueous Mercury
Blasch Precision Ceramics, Inc. 580 Broadway Albany, NY 12204-2802	A Ceramic Material and Process for Use in Monolithic Ceramic Cross-Flow Filters
*Busek Company, Inc. 19 Kearney Road Needham, MA 02194-2505	High Temperature Brazing of Silicon Carbide
*Cambridge Hydrodynamics, Inc. P.O. Box 1403 Princeton, NJ 08542-1403	A Molecular Dynamic Aided Advanced Diagnostic Tool for Granular Flow
Charles Evans and Associates 301 Chesapeake Drive Redwood City, CA 94063-4723	An In-Situ Microanalysis of Coal Flyash: Quantitative Correlation of Organic Surface Chemistry and Particle Composition
*Conductus, Inc. 10623 Roselle Street San Diego, CA 92121-1506	A Superconducting Magnetometer/Gradiometer for Advanced Geophysical Imaging
Containerless Research, Inc. 910 University Place Evanston, IL 60201-3149	An Apparatus for Structural Analysis of High Temperature Materials Using Synchrotron Radiation
*Correlations Company P.O. Box 187 Socorro, NM 87801-0187	Forecasting Reservoir Thickness with Fractals
Cryogenic Applications F, Inc. 450 Bacon Springs Lane Clinton, TN 37716-5311	A Continuous Cryopump/Pellet-Fabrication Apparatus for Fusion

*Project provided with funding continuity following application submission by January 17, 1995

Duly Research, Inc. 1912 MacArthur Street Rancho Palos Verdes, CA 90732	A High-Yield and Low-Emittance Positron Source from Coherent Laser-Electron Collisions
EDTEK, Inc. 14704 Southeast 100th Street Renton, WA 98059-3750	An Infrared Bandpass Thermophotovoltaic Filter Production Process
EIC Laboratories, Inc. 111 Downey Street Norwood, MA 02062-2668	Economical Photochromic Films Based on Metal Oxides
EXPORTech Company, Inc. P.O. Box 588 New Kensington, PA 15068-0588	Pulverizer Modification for Pyrite Separation at the Power Plant
*Electronic Power Conditioning, Inc. 1895 Northwest 9th Street Suite A Corvallis, OR 97330-2144	A Resonant Converter for Universal Wind Application
*Eltron Research, Inc. 2830 Wilderness Place, #E Boulder, CO 80301-5455	A Membrane Reactor for the Spontaneous Conversion of Natural Gas and Carbon Dioxide Mixtures into Valuable Feedstock
Eltron Research, Inc. 2830 Wilderness Place, #E Boulder, CO 80301-5455	Tubular Catalytic Membrane Reactors for the Spontaneous Conversion of Humidified Natural Gas to Synthesis Gas
Eltron Research, Inc. 2830 Wilderness Place, #E Boulder, CO 80301-5455	A Long Life Perovskite Oxygen Electrode for Calcium and Lithium Oxide Processing in Nuclear Fuel Cycles
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06813	A Multi-Functional Component to Simplify Fuel Cell Power Plants
Envirogen, Inc. 4100 Quakerbridge Road Lawrenceville, NJ 08648-4702	Development and Application of Gene Probes to Determine Degradation Potential and to Improve In-Situ Bioremediation Efforts
Environmental Elements Corporation 3700 Koppers Street P.O. Box 1318 Baltimore, MD 21203	Flue Gas Cleanup Using a Novel Corona Generator

*Project provided with funding continuity following application submission by January 17, 1995

FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236	A Gatling Micro Pulse Gun for Microwave Frequency Multiplying
G. H. Gillespie Associates, Inc. P.O. Box 2961 Del Mar, CA 92014-5961	The Particle Beam Optics Interactive Computer Laboratory (PBO Lab)
G. H. Gillespie Associates, Inc. P.O. Box 2961 Del Mar, CA 92014-5961	A Unique Educational Game with Interactive Tutorials for Learning about Accelerators, Detectors, and Particle Physics
Gautier-Downes and Associates 2656 Montrose Place Santa Barbara, CA 93105-2143	Computer Games to Teach Geography: El Nino: Mysteries of the Pacific and Mysteries of the Antarctic
Haimson Research Corporation 3350 Scott Boulevard Building 60 Santa Clara, CA 95054-3122	An Efficient Higher-Order Multi-Mode High Power Microwave Amplifier
*Haimson Research Corporation 3350 Scott Boulevard Building 60 Santa Clara, CA 95054-3122	A Radio Frequency Chopped, Low Emittance High Voltage Electron Source for a 30 MeV, Picosecond Bunch, High Gradient 17 Gigahertz Accelerator
Hi-Z Technology, Inc. 6373 Nancy Ridge Drive San Diego, CA 92121-2247	High-Temperature Thermally-Stable Multi-Layer Quantum Well Films
Hyper-Therm High-Temperature Composites, Inc. 18411 Gothard Street Units B and C Huntington Beach, CA 92648-1235	A Multilayer Silicon Carbide Fiber Coating for Toughened, Neutron Radiation-Resistant Silicon Carbide/Silicon Carbide Composites
IGC Advanced Superconductors, Inc. 1875 Thomaston Avenue Waterbury, CT 06704-1039	Economical and Reliable Niobium-Tin Conductors via Innovations in Stabilizers
*IGC Advanced Superconductors, Inc. 1875 Thomaston Avenue Waterbury, CT 06704-1039	Improvement in the Loss and Critical Current Density Properties of Internal-Tin Niobium-Tin
IGC Advanced Superconductors, Inc. 1875 Thomaston Avenue Waterbury, CT 06704-1039	Improvement in the Characteristics of Ternary Niobium-Titanium-Tantalum Alloys

*Project provided with funding continuity following application submission by January 17, 1995

Industrial Filter and Pump Manufacturing Company 5900 Ogden Avenue Cicero, IL 60650-3888	Simultaneous Hot Desulfurization and Improved Filtration in Coal Utilization Processes
InterScience, Inc. 105 Jordan Road Troy, NY 12180-8343	A Spatial Detector Array for Measuring the Turbulence Distribution with the Heavy Ion Beam Probe
J Integral Engineering 165 Southwest Tualatin Loop West Linn, OR 97068-9733	Cost Effective Stimulation of Shallow Oil and Gas Wells Using High Energy Gas Fracturing Fielded Without a Wireline or Workover Rig
JX Crystals, Inc. 1105 12th Avenue Northwest Suite A2 Issaquah, WA 98027-8994	A Clean and Efficient Thermophotovoltaic Generator for Electric Vehicles
*Jentek Sensors, Inc. 1616 Soldiers Field Road Boston, MA 02135-1181	Application of the Meandering Winding Magnetometer to an In-Situ Determination of Age Related Degradation
Jet Process Corporation 25 Science Park New Haven, CT 06511-1968	Jet Vapor Deposition of Multilayer and Nanocluster Thick Film Targets for Radioactive Nuclear Beams and Medical Applications
MJB Consulting 1415 Country Ridge Drive DeSoto, TX 75115-7423	A Multimedia Software Tutorial on Superconducting Accelerator Magnets
*MacConnell Research Corporation 11339 Sorrento Valley Road San Diego, CA 92121-1303	Low Cost Automated Preparation of Plasmid, Cosmid, and Yeast DNA
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025-1516	Membrane Module Development for a Natural Gas Dehydration Process
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025-1516	Highly Selective Membranes for the Separation of Organic Vapors Using Superglassy Polymers

*Project provided with funding continuity following application submission by January 17, 1995

Modern Building Systems, Inc. P.O. Box 110 9493 Porter Road Aumsville, OR 97325-0110	Design and Evaluation of Energy Efficient Modular Classroom Structures
Northwest Fuel Development, Inc. 4064 Orchard Drive Lake Oswego, OR 97035-2406	Continuous Pressure Swing Adsorption (CPSA) for Nitrogen Rejection from Natural Gas
Praxis Engineers, Inc. 852 North Hillview Drive Milpitas, CA 95035-4544	Development of Expansive Cements Using Dry Flue Gas Desulfurization (FGD) Solid Wastes
*R. Lynette and Associates, Inc. 15042 Northeast 40th Street Suite 206 Redmond, WA 98052-5353	Wind Turbine Power Electronics with Hybrid Integrated Circuits
*Research Development Corporation 2875 Towerview Road Suite A4 Herndon, VA 22071-3205	An Intelligent Tutoring Game to Teach Scientific Reasoning
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143-4228	Removal of Hydrogen Sulfide from Natural Gas by Electron Beam Irradiation
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143-4228	Ultrasensitive In-Situ Detection of Toxic Flue Emission
*Scientific Digital Visions, Inc. 954 Emory Street San Jose, CA 95126-1853	Innovative Software for Nuclear Physics Education
Selee Corporation 700 Shepherd Street Hendersonville, NC 28792-6472	A Novel High Strength Ceria-Zirconia Toughened Alumina Ceramic with Superior High Temperature Corrosion and Erosion Resistance
Solar Design Associates P.O. Box 242 Harvard, MA 01451-0242	Highly Integrated Modular DC-AC Inverters for Photovoltaic Systems
*Solar Engineering Applications Corporation P.O. Box 62246 Sunnyvale, CA 94088-2246	A Low Cost, Low-Loss, Volume-Manufacturable Lead Attachment Method for Solar Cells

*Project provided with funding continuity following application submission by January 17, 1995

Space Power, Inc. 621 River Oaks Parkway San Jose, CA 95134-1907	Design and Applications of Close-Spaced Thermionic Converters with Novel Isothermal Electrodes
*Spectral Sciences, Inc. 99 South Bedford Street, #7 Burlington, MA 01803-5169	An Off-Line-Locked Laser Diode Sensor (OLDS)
Spectrum Data, Inc. P.O. Box 3100 Kent, WA 98032-0202	Security Monitoring Systems: Sensors, Communications, and Computing
Spire Corporation One Patriots Park Bedford, MA 01730-2396	High Energy Resolution Cadmium-Zinc-Telluride Radiation Detectors for Nuclear Verification
Steven Winter Associates, Inc. 50 Washington Street Norwalk, CT 06854-2710	Design of a Family of Advanced Passive-Solar Modular Classrooms
*Surmet Corporation 33 B Street Burlington, MA 01803-3406	Ductile Joining of Plasma Facing Components to Copper
Surmet Corporation 33 B Street Burlington, MA 01803-3406	Low Cost Substrates for Micro-Strip Gas Chambers
Surmet Corporation 33 B Street Burlington, MA 01803-3406	Carbon-Carbon to Copper Joining for Fusion Reactor Applications
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033-1916	A Long Life Zinc-Oxide-Titanium-Oxide Sorbent
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033-1916	Fullerene-Based Catalysts for Heavy Oil Upgrading
Thermacore, Inc. 780 Eden Road Lancaster, PA 17601-4794	A Porous Metal Cooled Klystron Collector
*Thermal Electric Devices, Inc. 1704 Stanford Drive, SE Albuquerque, NM 87106-3323	Development of Metal Hydride Materials for High Coefficient of Performance Heat Pumps

*Project provided with funding continuity following application submission by January 17, 1995

Third Wave Technologies, Inc. 2800 South Fish Hatchery Road Madison, WI 53711-5399	Signal Amplification for Specific Nucleic Acid Detection
Vista Control Systems, Inc. 134-B Eastgate Drive Los Alamos, NM 87544-3304	A Framework for a General Purpose Intelligent Control System for Particle Accelerators
Weld Star Technology, Inc. 8204 Gondola Drive Orlando, FL 32809-6735	A Low-Cost Infrared Sensor-Based System for Robotic Welding
WhistleSoft, Inc. 168 Dos Brazos Los Alamos, NM 87544-2431	A Multimedia Tutorial for Charged-Particle Beam Dynamics

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*Project provided with funding continuity following application submission by January 17, 1995

DOE/ER-0655

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE II AWARDS

1995

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager
19901 Germantown Road
Germantown, MD 20874-1290

DOE/ER-0655

SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE II AWARDS

1995

U.S. Department of Energy
Office of Energy Research
SBIR Program Manager
19901 Germantown Road
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PREFACE

The SBIR program enables DOE to obtain effective, innovative solutions to important problems through the private sector, which has a commercial incentive to pursue the resulting technology and bring it to the marketplace. The growing number of awardees, many of them started in business in response to SBIR solicitations, is becoming a significant resource for the solution of high risk, high technology problems for the Department. As detailed below, this publication describes the technical efforts and commercialization possibilities for SBIR Phase II awards in 1995. It is intended for the educated layman, and may be of particular interest to potential investors who wish to get in on the ground floor of exciting opportunities.

The Federal SBIR Program

This program, now completing its thirteenth year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Eleven Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over $100 million. The agencies were required to set aside 2.0% of those budgets in Fiscal Year (FY) 1995 to fund SBIR projects. (This amounted to about $70 million in FY 1995 for the Department of Energy.) Each agency solicits proposals from small science- and technology-based US firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to $75,000 in FY 1994. Phase II is the principal research or R&D effort, and the awards were as high as $750,000 in FY 1995 for work to be performed in a period of up to two years. Phase III is the commercial application of the research or R&D effort by the small businesses using non-Federal funding or, alternatively, it may involve follow-on non-SBIR Federal contracts for products or services desired by the Government. The program continues to strengthen the role that small, innovative firms play in meeting the Nation's research and development needs and in commercialization of ideas developed through federally funded R&D.

Phase II Awards for FY 1995

Contained in this booklet are abstracts of the Phase II awards made in FY 1995 under the DOE SBIR program.

DOE received 2276 grant applications in response to its annual solicitation, and on June 10, 1994, 216 were selected for Phase I funding. The Phase II SBIR program competition was limited to the 212 projects that subsequently proceeded to Phase I awards.

Applicants desiring to maintain project funding continuity from Phase I to Phase II were invited to submit their grant applications to DOE not later than January 17, 1995, approximately 6 weeks before the end of their Phase I grants. Forty-five Phase II applications were submitted by that date, and 17 were selected for Phase II awards; those projects were then able to continue without funding interruption between Phases I and II. The deadline for the submission of Phase II applications for applicants not seeking to maintain project funding continuity was April 24, 1995. From the 147 applications submitted by this date and from the 28 unfunded applications from the January 17, 1995, submissions, 64 were selected for Phase II awards. The 81 Phase II projects described in this book consist of these 64 projects and the 17 projects that were funded from the January 17 submissions. The listed amount of each award, in many instances, is subject to completion of award negotiations.

The DOE SBIR Program

DOE's FY 1995 annual Solicitation contained 44 technical topics in the areas of basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, energy efficiency and renewable energy, fossil energy, and nuclear energy, environmental management, nonproliferation and national security, and environment, safety and health. There is keen competition because awards are made solely on the basis of scientific and technical merit, regardless of the technical topic.

As a measure of the program's success, twelve DOE SBIR projects have received R&D-100 Awards from Research and Development Magazine, which selects the 100 most significant technical products each year. In addition, five DOE awardees were chosen among the 500 fastest-growing American private companies, in the December 1991 issue of Inc. Magazine, based on their growth in sales. Also, from the first seven cycles of awards (Phase II projects completed between 1986 and 1992), DOE SBIR winners have already received approximately $380 million in Phase III funding, which is double the SBIR support they were given. This number is expected to grow significantly in the next few years.

The DOE SBIR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. In the first year of Phase II awards (1984), a system was devised and implemented that allowed Phase I awardees who felt they were ready to submit their Phase II applications before their Phase I grants ended, to do so. For each of the twelve years in which Phase II awards have been made, such grantees who were chosen for Phase II funding were able to begin their projects without an interruption in funding. Since 1984, about 40 per cent of the Phase II awardees have had continuous funding between Phases I and II.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, DOE has instituted a special training project, supported by non-SBIR funds. For the past six years, successful Phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participation in the 1991 and 1993 projects, the SBIR companies have already received more than $50 million for commercialization of their SBIR research. More than half of the firms that completed these projects have received further funding for their work. Sources of capital that wish to consider participation in future programs should contact Dr. Robert Berger, U S Department of Energy SBIR Program, ER-33, 19901 Germantown Road, Germantown, MD 20874-1290, (telephone 301-903-3054).

Robert E. Berger
Acting SBIR Program Manager

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ENGINEERING ADVANCES FOR PHOTOVOLTAIC SYSTEMS

1

A Trimode Power Processor to Optimize Photovoltaic, Battery, and Diesel-Generator Sources for Economic Stand-alone Power Plants--Abacus Controls, Inc., P.O. Box 893, Somerville, NJ 08876-0893; (908) 526-6010
Mr. George A. O'Sullivan, Principal Investigator
Mr. George A. O'Sullivan, Business Official
DOE Grant No. DE-FG05-94ER81689
Amount: $741,981

Currently, diesel generators are the primary source of electric power in remote areas where the cost of constructing long power lines exceeds the cost of fuel delivery. Advances in photovoltaics (PV) technology now make it cost effective to build and operate a hybrid power plant. A trimode power processor fulfills an important control function in remote village applications of PV. It optimizes the use of three sources of energy, PV, diesel, and battery, by minimizing diesel fuel consumption and by using the maximum power available from the PV array. The positive impact of applying the trimode power processor with a newly invented power quality enhancement controller was demonstrated with detailed computer simulations in Phase I. The simulations illustrated how battery charging will be used in a control strategy to apply the optimum load to the diesel generator. The processor reduces the fuel consumption of the diesel generator to a minimum by presenting itself as the perfect electrical load to the generator. In Phase II, hybrid systems will be developed that combine the energy sources from PV, batteries, and diesel-generators, and a 50 kW three phase unit will be tested to prove its worthiness in actual field conditions. Economical feasibility will be demonstrated for small power plants in many parts of the world.

Anticipated Results/Potential Commercial Applications as described by the awardee: The application of PV energy at remote locations where reliability of supply requires a diesel generator will be less costly to operate by reducing the run time of the diesel generator. The numerous benefits include longer times between maintenance for the diesel engine and better power quality from the generator.

2

Highly Integrated Modular DC-AC Inverters for Photovoltaic Systems--Advanced Energy Systems, Inc. (formerly Solar Design Associates), P.O. Box 242, Harvard, MA 01451-0242; (508) 456-6855
Dr. Robert H. Wills, Principal Investigator
Mr. Steven J. Strong, Business Official
DOE Grant No. DE-FG02-94ER81862
Amount: $750,000

One of the major costs in photovoltaic (PV) systems is the direct current to alternating current (DC-to-AC) inverter. This project addresses new design options for distributed, highly-integrated modular inverters for PV power systems which are well suited to low-cost, high-volume production. In Phase I, a small, modular, innovative, ≥100 watts, utility-interactive PV inverter was developed. The prototype inverter measures just 11.75 x 3.72 x 1.5 cubic inches which is small enough to mount directly on the back of a PV module. The measured efficiency of the prototype inverter was 96% peak, significantly higher than any current commercial units. In Phase II, the inverter's control hardware (microcontroller, communications, timing clock and dividers, sine-generation memory and addressing counter, and inverter control) will be integrated into a mixed-signal (i.e. both analog and digital) Application Specific Integrated Circuit (ASIC). Since about 30% of the cost and size of the inverter is in this control area, considerable savings are possible. The combination of logic and power switches is known as "Smart Power". This will be the first application of Smart Power for PV applications. The Phase II goal is an inverter design that, in mass production, can be manufactured for under $0.25 per peak watt.

Anticipated Results/Potential Commercial Applications as described by the awardee: The effort should lead to the development of an "AC Module",a potentially new product which integrates the PV module and the inverter. This AC module should lead to simpler and lower cost PV systems. The AC module, as a new consumer product, has the potential to revolutionize the PV industry.

3

Low Cost, Low-Loss, Volume-Manufacturable Lead Attachment Method for Solar Cells---Solar Engineering Applications Corporation, 3500 Thomas Road, Suite E, Santa Clara, CA 95054-2049; (408) 986-9231
Mr. Neil Kaminar, Principal Investigator
Mr. Don Curchod, Business Official
DOE Grant No. DE-FG03-94ER81863
Amount: $749,928

Cost effective, efficient, current extraction from concentrating photovoltaic (PV) cells has been a barrier to low cost PV power. An innovative external bus bar attachment method for concentrating PV cells has been developed which promises to both reduce manufacturing time and improve cell output, thereby lowering overall costs. Phase I resulted in a workable specific design to form wire attachment leads to the top and bottom contacts of the cell which minimized the on-cell bus bar area, reduced grid obscuration, used off-shelf materials, and was suitble for automated production. Prototypes were built and tested which indicated a 12% increase in output and a 30% reduction in cost. In Phase II, the Phase I concepts will be refined, automated volume assemly equipment will be designed, and this equipment will be constructed and tested in order to terminate concentrating PV cells resulting in cell subassemblies according to this improved design.

Anticipated Results/Potential Commercial Applications as described by the awardee: The world market for low-cost, non-polluting electric power is enormous. This project will permit production of volume PV power at under 5¢/KW-hr whereas the average US cost is approximately 8¢/KW-hr, and the average world price is greater that 20¢/KW-hr. The work has applicability to other solar cells and should help US industry dominate this new important pollution-reducing trillion-dollar market.

INDUSTRIALIZED PASSIVE SOLAR BUILDINGS

4

Modular/Transportable Classroom Structures--Aspen Systems, Inc., 184 Cedar Hill Street, Marlborough, MA 01752-3017; (508) 481-5058
Dr. Glen Deming, Principal Investigator
Dr. Kang Lee, Business Official
DOE Grant No. DE-FG02-94ER81711
Amount: $749,113

Changing demographics throughout the country cause many school systems to experience significant fluctuations in student population, resulting in immediate, though possibly temporary, needs for more classroom space. Each year in the United States, tens of thousands of transportable classroom modules are used as a means of rapidly providing required space at a reasonable cost. This project involves a novel approach to the design and manufacure of transportable classrooms. Phase I resulted in the identification, development, and integration of several key energy efficient technologies including the utilization of structural insulated panels throughout the walls, floor, and roof. This construcion technique significantly reduces manufacturing labor while producing a high strength, extremely tight and well insulated shell. It also allows the integration of an innovative attic collector used for both daylighting and thermal conditioning. A control system provides heating, cooling, ventilating, and lighting on demand in response to detected occupancy and preprogrammed time schedules. In Phase II, an experimental test bed will be fabricated to quantify and optimize the performance of individual components as well as the integrated structure. A full scale prototype will then be designed to be as energy efficient as possible while remaining cost competitive.

Anticipated Results/Potential Commercial Applications as described by the awardee: The integrated classroom is expected to consume up to 75 percent less energy than the conventional equivalent. The novel structures will not only have significantly reduced energy consumption, but will incorporate recycled and recyclable materials. Since tens of thousands of these buildings are manufactured each year, the final result of this project should be a significant reduction in the Nation's energy consumption.

5

Design and Evaluation of Energy Efficient Modular Classroom Structures--Modern Building Systems, Inc., P.O. Box 110, 9493 Porter Road, Aumsville, OR 97325-0110; (503) 749-4949
Mr. James Stanard, Principal Investigator
Mr. Donald Rasmussen, Business Official
DOE Grant No. DE-FG03-94ER81814
Amount: $750,000

Modular classroom units exhibit poor energy performance and often fail to provide a physically and psychologically healthful environment for teachers and students. In part, this situation is due to low construction budgets. Design modifications are required to improve energy performance, thermal comfort, ease of transportation, flexibility of use, and the psychological well being of students and teachers. In Phase I, detailed computer simulations were used to gauge improvement over baseline statistics gathered from existing modular classrooms in a variety of climatic regions of the United States. For schools whose primary concern is low initial cost, an alteration of the basic classroom module was developed to improve its energy performance with minimum increase in cost. The features investigated included wall-integrated ventilation air solar preheaters, additional windows for daylighting and passive ventilation cooling, electric lighting controls, occupancy sensors, window shading devices, and down-sized heating, ventilation, and air conditioning. Phase II will develop a range of options to meet various budgets: (1) a refinement of the module developed in Phase I which will also be applicable to retrofitting in-place units, (2) a perimeter-insulated foundation system which can be combined with the energy features from the Phase I unit, and (3) a module with passive energy benefits and greater architectural complexity for schools with a longer term perspective.

Anticipated Results/Potential Commercial Applications as described by the awardee: The impact of these innovations on the market in the energy-conscious Pacific Northwest could be significant. They could become a voluntary requirement of most, if not all, school districts in the region. That could translate into 200 to 300 classrooms per year. With an average value of $30,000 per classroom the market potential is great. In the Nation as a whole, these innovations could be beneficial to thousands of school districts through many manufacturers.

6

Design of a Family of Advanced Passive-Solar Modular Classrooms--Steven Winter Associates, Inc., 50 Washington Street, Norwalk, CT 06854-2710; (203) 852-0110
Mr. Steven Winter, Principal Investigator
Ms. Marie Costello, Business Official
DOE Grant No. DE-FG05-94ER81870
Amount: $750,000

This project involves the development of high performance passive-solar modular classrooms. Phase I produced a unique expert system, a decision making tool, for the creation of classroom designs and specifications that satisfy widely varying criteria and user needs throughout the U.S. Phase II will consist of refining, commercializing, and evaluating the design procedures developed in Phase I. It will comprise: (1) refinement of the expert system and its translation into a software package suitable for applications by school construction administrators, architects and design professionals, and modular classroom manufacturers, (2) formation of an industry consortium, under the aegis of the Modular Building Institute, to promote the purchase and construction of energy-efficient and cost effective modular classrooms designed with the software, (3) development and implementation of a broad marketing plan to merchandise the software and to train and counsel software users among the various industry sectors, and (4) evaluation of these results and development of strategic plans for Phase III and beyond.

Anticipated Results/Potential Commercial Applications as described by the awardee: The primary result of Phase II will be a commercially available, software package that is a unique expert system for the design and specification of modular classroom buildings. This decision making tool will be applied by school construction administrators to develop design and procurement criteria and specifications, by architects and design professionals, for architecture/engineering solutions for classrooms, and by modular classroom manufacturers to prepare construction bids and bid documents.

WIND TURBINES: EFFICIENCY IMPROVEMENT USING ADVANCED POWER ELECTRONICS

7

A Look-Ahead Adaptive Control System (LACS) for Wind Turbine Generators--AeroVironment, Inc., 222 East Huntington Drive, Monrovia, CA 91016-3500; (818) 357-9983
Dr. Kenneth H. Underwood, Principal Investigator
Mr. Thomas Zambrano, Business Official
DOE Grant No. DE-FG03-94ER81700
Amount: $750,000

When a wind turbine is operating in strong winds near its maximum power rating, a gust can over stress the structural and electrical systems. The over design required for reliability under such stresses increases the cost of the wind turbine and its installation and maintenance. The ability to anticipate the wind and turbulence conditions and respond to those conditions may significantly reduce these costs. The Look-ahead Adaptive Control System (LACS) is an adaptive controller that has the ability to monitor the strength of the incoming wind gusts and predict when they will arrive at the wind turbine. This provides time for pitch modification of a wind turbine with variable pitch blades, which minimizes stresses and results in a more economical and reliable wind turbine system. A sonic detection and radar system (sodar) has been developed to remotely profile atmospheric winds. One version, the minisodar, operates at a frequency of 4500 Hz and measures winds from 15 meters to 200 meters in the vertical plane. During Phase I, the minisodar was adapted to provide measurements on the horizontal plane. In effect the minisodar was configured to "look-ahead" at the oncoming wind. In this configuration the minisodar was able to provide wind and wind gust information several seconds ahead of impact during strong wind conditions, adequate for the look-ahead adaptive controller. In addition, Phase I modeled the ability of LACS concept to work effectively with variable pitch wind turbine designs. During Phase II, a specialized 10 Khz turbine mounted sensor will be developed to detect and track wind gust. It will be adapted from the sodar technology and designed to measure the wind field upwind of the wind turbine to provide wind gust and turbulence information for adaptive wind turbine power control systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: Direct integration with wind turbine controllers for reduction of output power fluctuation is envisioned. This could include development of an integrated expert system or neural network with a fuzzy logic adaptive controller which, given information about wind turbine power output, would automatically configure itself to a given wind turbine control system and provide a modified output power signal for use by the wind turbine controller.

8

A Resonant Converter for Universal Wind Application--Electronic Power Conditioning, Inc., 1895 Northwest 9th Street, Suite A, Corvallis, OR 97330-2144; (503) 753-7220
Dr. Hian K. Lauw, Principal Investigator
Mr. Dallas A. Marckx, Business Official
DOE Grant No. DE-FG03-94ER81747
Amount: $739,861

With a variable-speed generation (VSG) system, a wind turbine can turn at any speed and still produce constant frequency and voltage power which is compatible with the grid. The primary benefits of VSG include increased energy production, increased power capacity, soft starts, control of torque perturbations, dynamic electrical braking, and power factor control. All of the modern techniques for implementing VSG rely on a power electronic converter or conditioner. Conventional converters have several well-known problems: high cost, excessive power losses, excessive harmonics, damage to the generator windings, poor power factor, and audible noise. An innovative resonant converter known as the Unipolar Series Resonant Converter (USRC) will make dramatic improvements in each problem area. The USRC uses thyristors with zero voltage and current switching, thus minimizing losses and enabling high modulation frequency. It is also inherently bidirectional and produces sinusoidal voltage within IEEE 519 standards at both the input and output with little or no supplemental filtering, thus greatly reducing size and cost. In Phase I, a 400 kW USRC that can be used in virtually every practical configuration which enables VSG was designed and assessed as to technical and economic feasibility. In addition, a more specialized resonant converter which can further reduce cost and increase efficiency in some variable-speed configurations was identified. In Phase II, both resonant designs will be assembled, characterized thoroughly in the laboratory, and then installed in the field in several wind turbines.

Anticipated Results/Potential Commercial Applications as described by the awardee: A successful project will reduce substantially the cost of energy from wind turbines by providing the most advanced power electronics for variable-speed capability. With other improvements, the cost of energy will be reduced below 4 cents per kW, a threshold that will cause the widespread use of wind power.

9

Wind Turbine Power Electronics with Hybrid Integrated Circuits--R. Lynette and Associates, Inc., 1830 Bering Drive, San Jose CA 95112; (415) 721-1300
Dr. T. S. Jayadev, Principal Investigator
Mr. Robert Lynette, Business Official
DOE Grant No. DE-FG03-94ER81840
Amount: $749,800

An innovative generation system concept was developed in Phase I of this project, which has the potential to reduce the cost of energy from wind power plants by 20%. The generating system consists of a novel generator and a power electronics module using emerging technologies of high power Insulated Gate Bipolar Transistors and Hybrid Integrated Circuits. This system can solve the challenging problem of finding a cost-effective generating scheme for direct drive, variable speed wind turbines. In Phase I, the technical feasibility of the concept was proved by detailed modeling and in depth analysis of the proposed generation system. Conceptual design of this system was developed in enough detail to provide a basis for calculating the projected cost of the system. This calculation showed that the cost of the system is in the same cost range as the equipment it is replacing in currently used, geared drive, constant speed systems. However, because it can generate significantly more energy, the cost of energy produced by the wind power systems is reduced. In Phase II, the new technology will be developed to the level of readiness required to launch commercial products in Phase III. This involves fabricating a 12.5 kW generating system and extensively testing it in house and also at the National Renewable Energy Laboratory, where a sophisticated test facility has been built to test low speed generators. The 12.5 kW prototype can directly lead to a product serving village power markets. Technology developed in Phase II will be scaled up to a 100 kW modular unit. With this modular approach, the needs of utility scale wind power plants can be met.

Anticipated Results/Potential Commercial Applications as described by the awardee: One of the major advantages of the new system is that the largest gains are in low wind speeds (for example, a 20% gain in energy production at an annual average wind speed of 14 mph). Much of the world's potential wind sites have speeds in a range that is currently too low for economic wind power generation, but is viable with a 20% reduction in the cost of energy. The machine and power electronics under development in this project also have direct applications in industrial speed control and energy conservation. Because of their potentially high efficiency and low cost, they are cost effective in industrial drives for pumps and fans. The Hybrid Integrated Circuit Power Electronics developed in this project can significantly increase efficiency and lower the cost of inverters for photovoltaic and battery storage systems.

LOW-LEVEL MIXED WASTE PROCESSING

10

An Acoustic Plate Mode Sensor for Aqueous Mercury--BIODE, Inc., 2 Oakwood Road, Cape Elizabeth, ME 04107-2025; (207) 883-1492
Dr. Douglas McAllister, Principal Investigator
Dr. Douglas McAllister, Business Official
DOE Grant No. DE-FG02-94ER81717
Amount: $736,880

There is a critical need for a fast, simple sensor for aqueous mercury in waste, surface, and groundwater. This sensor is required to rapidly detect nanogram per liter levels of mercury. The sensor should be capable of direct immersion in solution and should provide continuous data on either cumulative mercury exposure or instantaneous concentration. One method of detecting part per billion levels of mercury in solution uses a novel class of piezoelectric sensors, known as the shear horizontal acoustic plate mode. These sensors measure the perturbation of an acoustic wave, in situ, to changes in electrical and mechanical properties. Phase I indicated that the sensor under examination has an excellent chance of meeting these requirements. Phase II will expand on the Phase I results while exploring improved methods of regenerating the sensor. Electrochemical regeneration, crudely demonstrated Phase I, will be refined, as will the packaging and measurement electronics. Improvements to the measurement system and device design will allow the Phase I detection limit of approximately one ng (total) in a one ml sample to be reduced to ~50 pg (total). If the project is completely successful, electrochemical techniques will allow continuous monitoring rather than the cumulative response demonstrated in Phase I.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned research will lead to field and factory-based monitoring instruments for aqueous mercury which will be capable of performing discrete, in-situ measurements of mercury. Although not directly addressed, other films could be developed for the selective detection of other contaminants (e.g., cadmium or uranium), volatile organic compounds, or gaseous pollutants (e.g., nitrogen oxides, sulfur dioxide, or hydrogen sulfide).

11

An Off-Line-Locked Laser Diode Sensor (OLDS)-Spectral Sciences, Inc., 99 South Bedford Street, #7, Burlington, MA 01803-5169; (617) 273-4770
Dr. Steven C. Richtsmeier, Principal Investigator
Dr. Fritz Bien, Business Official
DOE Grant No. DE-FG02-94ER81865
Amount: $750,000

This project addresses the monitoring of hazardous off-gas streams containing HF, HC1, NO_X, H_2S, etc., produced from thermal treatment of mixed wastes. Measurements of these and other gases are needed for compliance with the Clean Air Act and as diagnostics for emission control systems and combustion efficiency. In Phase I, sensitive, real-time monitoring of multiple and unstable gas species was demonstrated with a laboratory breadboard. The key innovation is the ability to rapidly and reproducibly shuttle the output wavelength of a single diode laser between two or more arbitrary molecular absorption lines. Advantages over previous diode laser sensors include: (1) benign, stable species can be used to provide reference lines for measuring unstable or toxic gases, (2) it permits near-simultaneous monitoring of multiple species and elimination of cross-sensitivities. In Phase II a prototype diode laser based, in-situ continuous emissions monitor (CEM) for multiple gas species will be developed and field tested. A commercial CEM sensor will be developed in Phase III in collaboration with a major instrument manufacturer.

Anticipated Results/Potential Commercial Applications as described by the awardee: The OLDS technology will have immediate and widespread use in both government and commercial waste processing facilities for real-time, in-situ monitoring of multiple toxic off-gases. The technology will also have a large commercial market in other continuous emission monitoring, ambient air monitoring, and process control applications. The OLDS monitor does not require a heated sample extraction system and offers significant advantages in cost, maintenance, and automation over currently available baseline techniques and commercial CEM instruments.

ARMS CONTROL AND NONPROLIFERATION VERIFICATION AND DETECTION TECHNOLOGY

12

Security Monitoring Systems: Sensors, Communications, and Computing--Spectrum Data, Inc., P.O. Box 3100, Kent, WA 98032-0202; (206) 824-9337
Mr. John J. Burlingame, Principal Investigator
Mr. Rodney W. Davidson, Business Official
DOE Grant No. DE-FG03-94ER81866
Amount: $749,144

Automatic detection of human presence is required in security environments. Systems must operate in and around varying backgrounds and with a near-zero false alarm rate. In this project, video acquisition will be time coordinated with other sensors, wireless spread spectrum communications, and various image processing systems to detect the presence of human intruders, and the alarm will be communicated to the monitoring station with near 100% accuracy. In Phase I, it was shown that several inexpensive nodes placed in a security environment can simplify the image recognition task, increase real-time performance, and provide maximum security coverage on an economical budget. Test bed results proved that digital image recognition is feasible and allowed the determination of the number of operations required, as well as the compression, decompression, and communications requirements. Phase II will develop a very low cost system that supports real-time image processing, has advanced image recognition software, and can be connected to a monitoring station by means of telephone lines or wirelessly. An advanced industrial security system will be designed which incorporates the above elements plus advanced image recognition and high integrity safeguards against sophisticated intruders.

Anticipated Results/Potential Commercial Applications as described by the awardee: Two separate products are planned based on the same core wireless video with image recognition technology: one for the consumer and one for high end industrial use. The node cost will be low, and the system should be easily installed for both the consumer market and the advanced industrial applications.

INTERNATIONAL ATOMIC ENERGY AGENCY SPECIAL SAFEGUARDS INSPECTIONS

13

Plutonium Assay Using Superheated Drop Technology in Support of International Atomic Energy Agency Safeguards--Apfel Enterprises, Inc., 25 Science Park, Suite 676, New Haven, CT 06511-1968; (203) 786-5599
Mr. Jesus D. Martin, Principal Investigator
Mr. Robert E. Apfel, Business Official
DOE Grant No. DE-FG05-94ER81707
Amount: $618,076

The non-destructive detection of plutonium 239 represents a substantial challenge for those agencies charged with the responsibility of monitoring the Nuclear Non-Proliferation Treaty. Confidence in the reliability of this process is essential if the treaty is to be renewed by its current signers in 1995, and if those who are currently not signers are to put their faith in the treaty. This challenge is augmented by the problem of monitoring the handling of nearly 200 tons of plutonium created by the superpowers during the cold war. A compact instrument is needed that will allow inspectors to determine reliably the presence or absence of plutonium at a given site, the approximate amount of plutonium at the site, and the nature of that plutonium (e.g. enriched Pu-239). Although gamma spectrometry is sometimes a logical choice for indicating the presence of plutonium, it several instances it may fail. In this project, a simple and compact system, based on superheated drop (bubble) technology, will be constructed that provides sufficient spectral information about the plutonium sources to permit appropriate plutonium classification. Tests performed during Phase I confirmed theoretical predictions of the feasibility of this methodology and allowed the selection of a particular pair of superheated drop compositions to be used in the construction of a plutonium neutron monitor. Circuity was designed, and software was tested. Phase II will continue the tests and construction of the instrument, with the goal of producing a fully operational prototype for testing at DOE sites.

Anticipated Results/Potential Commercial Applications as described by the awardee: New instrumentation for plutonium monitoring will be developed that will assist in the effort of verifying compliance with the Nuclear Non-Proliferation Treaty and other nuclear arms control agreements. This instrumentation if modified, may also have application to environmental measurements of small amounts of plutonium in radioactive wastes.

14

High Energy Resolution Positive-Insulator-Negative Cadmium-Zinc-Telluride Radiation Detectors for Nuclear Verification--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; (617) 275-6000
Dr. Rengarajan Sudharsanan, Principal Investigator
Mr. Richard S. Gregorio, Business Official
DOE Grant No. DE-FG02-94ER81869
Amount: $749,853

There is a need for improved, miniaturized radiation detectors for on-site measurement of containerized nuclear material, particularly uranium and plutonium. High-purity germanium detectors currently available require cryogenic cooling and sodium iodide detectors lack the energy resolution necessary to identify plutonium accurately. Cadmium telluride detectors are a promising alternative but suffer from both material and device problems which have prevented them from reaching their potential of meeting the requirements of nuclear verification. Cadmium zinc telluride (CdZnTe) detectors with an increased detection volume and an improved charge collection are therefore needed. In Phase I, a room temperature CdZnTe positive-insulator-negative (p-i-n) detector with sensitivity and energy resolution superior to current CdTe detector technology was demonstrated. The improvement resulted from the CdZnTe deposition technology which preserved its high resistivity. Current-voltage data clearly showed diode behavior; the detector's performance was verified by measuring its gamma ray sensitivity and energy resolution. In Phase II, a portable, miniaturized detection system prototype for nuclear verification using improved CdZnTe detectors, will be developed. P-i-n CdZnTe detectors with detection volumes greater than 200 mm^3 will be employed and if necessary, the energy resolution will be improved using thermoelectric cooling.

Anticipated Results/Potential Commercial Applications as described by the awardee: Room temperature CdZnTe gamma ray detectors with sensitivities and energy resolution superior to those of competing technologies are needed for portable miniaturized probes to monitor uranium and plutonium in nuclear facilities. They will also find use in gamma spectroscopy, medical imaging, and x-ray astronomy.

INNOVATIVE FOSSIL SOLIDS AND LIQUIDS PROCESSING AND RELATED CROSSCUTTING APPLICATIONS

15

A Molecular Dynamic Aided Advanced Diagnostic Tool for Granular Flow--Cambridge Hydrodynamics, Inc., P.O. Box 1403, Princeton, NJ 08542-1403; (609) 683-1515
Dr. William S. Flannery, Principal Investigator
Ms. R. Karp, Business Official
DOE Grant No. DE-FG05-94ER81722
Amount: $749,975

There has been a rapid increase in both the quantity and diversity of the granular materials that are used in industry, creating an urgent need for a design and diagnostic tool for granular flows. The energy, metallurgical, food/agricultural, pharmaceutical, and chemical industries are but a few of the industries that use and/or require the handling of bulk solids. These industries all suffer large losses as a result of poor performance of bulk solids handling devices which are subject to frequent clogging, unsteady and erratic flows, undesirable separation, flooding, and even structural failure. Recent algorithmic advances as well as the availability of fast superworkstations enable the use of Molecular Dynamic (MD) simulations to study granular systems of up to the order of 1,000,000 particles in practically any desired geometry and for any prescribed geometrical or dynamical properties of the particles or boundaries. In Phase I, highly efficient simulators for rapidly sheared granular systems in two and in three dimensions were constructed and the dynamics of about one million particles were computed on superworkstations, demonstrating the technical feasibility of a MD simulation based diagnostic and design tool. In addition, a prototype user-friendly Graphical User Interface (GUI) was developed, ensuring the ease of use of this code. This GUI is based on advanced programming tools to provide portability across a variety of user platforms. Both user-friendliness and portability are deemed essential to the commercial success of the Phase II product. In Phase II the development of an advanced diagnostic and design tool for flowing granular materials and of the GUI will be completed. Numerous enhancements will be made to the code to extend the range of its industrial applicability, allowing arbitrary particle-particle and particle-wall interactions, and providing standard and advanced diagnostics. The development of a hybrid MD and continuum simulator will enable further extensions of the size of systems to be simulated. The resulting MD diagnostic and design tool should prove a significant contribution to the field of bulk solids handling.

Anticipated Results/Potential Commercial Applications as described by the awardee: This MD simulation code offers a relatively inexpensive, nonintrusive, and almost model independent means of design and troubleshooting in granular flow systems. Its versatility and ease of use (particularly through the GUI) will make it much faster (and cheaper) than standard methods of diagnosis or experimentally based design. As such, the MD code should quickly become a valuable tool in the design and operations of silos, chutes, pneumatic conveyors, drums, and fluidized beds in the energy and other industries. Realistic market estimates suggest about 100 user sites leading to a substantial commercial market.

16

Pulverizer Modification for Pyrite Separation at the Power Plant--EXPORTech Company, Inc.,
P.O. Box 588, New Kensington, PA 15068-0588;
(412) 337-4415
Dr. Robin R. Oder, Principal Investigator
Mrs. Marcia R. Oder, Business Official
DOE Grant No. DE-FG05-94ER81764
Amount: $750,000

Coal is dry-milled to 200 mesh topsize at pulverized-coal fired power plants to promote good combustion characteristics. The logical place for fine coal cleaning is in the pulverizer, which is already used by the power plant. The Mag-Mill is an innovative pulverizer/separator which uses magnetic separators incorporated into the mill structure to selectively extract hard mineral components, including iron pyrite, from the mill's internal circulation. In this project, Mag-Mill technology will be developed for cleaning coal in the pulverizer at pulverized coal-fired power plants. Phase I demonstrated that significant reductions in ash and sulfur levels can be achieved without significant energy loss and that magnetic separators can be retrofitted to existing pulverizers, thus saving capital costs to the utility. In Phase II, an on-line, full scale test will be conducted at a pulverized coal-fired power plant. The magnetic responsiveness of pound-lot quantities of 50 candidate coals will be tested to determine levels of ash and sulfur removal that can be achieved using a laboratory scale separator. Treatment of ton-lot quantities of selected coals will be demonstrated in a 1500 lb/hr pilot magnetic separator. Bowl, ball, and ring-race coal pulverizers will be sampled at power plants to obtain information on pulverizer operation which will be used to prepare a conceptual design of a Mag-Mill retrofit and to prepare a draft test plan for on-line testing. Following this, a final design and cost estimate will be prepared, and a separator with a capacity of up to 15 tons per hour will be built.

Anticipated Results/Potential Commercial Applications as described by the awardee: The Mag-Mill benefits the power plant operator by lowering fuel procurement, sulfur scrubbing, and power plant maintenance costs, and by increasing pulverizer throughput. Retrofitting a 1600 MW pulverized coal-fired power plant can save a utility in excess of $4,000,000 per year in scrubber costs alone. The market for Mag-Mill retrofits in the U.S. electric utility industry is estimated at $1.6 billion.

17

Fullerene-Based Catalysts for Heavy Oil Upgrading--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033-1916; (303) 940-2301
Dr. William L. Bell, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-94ER81879
Amount: $750,000

Heavy oils, including residues from crude oil distillation (resids), represent an abundant energy resource that is not fully utilized. It has been estimated that if only 20% of these crudes could be recovered, it would produce 1.27 million barrels of oil per day for the next 25 years. Use of heavy oils requires catalytic hydrogenation for removal of sulfur and nitrogen, and to lower the boiling range. Improved catalysts for heavy oil upgrading are highly desirable, and a promising area for improvement is the use of carbon catalyst supports, which show enhanced activity over traditional alumina supports. In Phase I fullerene-based catalysts, in which active metals are deposited onto carbon soot produced in conjunction with fullerenes, were investigated. Catalyst tests with model compounds and with an authentic petroleum resid identified an area in which the fullerene-based catalysts have significantly enhanced activity compared with catalysts based on alumina and on other forms of carbon. An engineering analysis demonstrated that the fullerene-based catalysts could be produced at competitive prices. Phase II will prepare and test the novel catalysts to determine the production methods for best performance. The tests will use both model compounds and authentic resids, in both batch and continuous processes. Phase II will also investigate methods to prepare fullerene-based catalyst supports as extrudates with an improved pore size distribution, which will allow use of these materials in a packed bed and will improve mass transport kinetics within the catalyst particles. Further experiments and analysis will estimate the cost of production of the fullerene-based catalysts and the cost of metal recovery from the spent catalyst. Phase II will include a large-scale, long-term test at a hydrotreating pilot plant. This test will allow direct comparison of the catalyst under development with current materials, both in activity and durability under operating conditions. Phase II will conclude with an analysis of the process economics. Using data acquired in Phase II on the catalyst activity and longevity, cost of catalysts production, product quality, and metal disposal after use, the cost to performance ratio of fullerene based catalysts for heavy oil upgrading will be estimated and compared with conventional catalysts.

Anticipated Results/Potential Commercial Applications as described by the awardee: A successful project will lead to improved fullerene-based catalysts for use in heavy oil upgrading, which can lower the cost of converting heavy oils to more valuable materials.

ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY FOR FOSSIL ENERGY

18

An Optical Technique for Non-Intrusive Characterization of Fine Particulates in Flue Gas Streams--Aerometrics, Inc., 550 Del Rey Avenue, Unit A, Sunnyvale, CA 94086-3528; (408) 738-6688
Dr. William D. Bachalo, Principal Investigator
Dr. William D. Bachalo, Business Official
DOE Grant No. DE-FG03-94ER81699
Amount: $725,000

As environmental awareness continues to grow, so does the need for more robust environmental monitoring instruments, including fine particle sizing instruments. Over the years, the study of fine particulate pollution has been relatively neglected compared with chemical pollutants such as ozone and sulfur dioxide. Particulates less than 10 microns are among the most dangerous atmospheric pollutants and are hazardous to human health. These fine particles include dust, soot, smoke, or tiny droplets of acid. The removal of contaminants, including particulates, from hot gas streams is also essential for the successful development of advanced coal utilization and conversion processes. Therefore, there is a need for the development of non-intrusive diagnostic instruments that can be used for on-line monitoring of particulate emission. In Phase I, the feasibility of using a coaxial laser beam arrangement for the accurate measurement of individual, non-spherical particles was demonstrated. A novel ratioing scheme was implemented to eliminate sizing errors that result from the Gaussian nature of the incident laser beams. The optical, electro-optical, and signal processing considerations for measuring particles in the size range 0.3 to 100 microns was addressed. This size range represents a signal dynamic range of almost 10^8 which is an engineering challenge. In Phase II, a prototype ratiometric particle sizer will be developed and tested.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned laser diagnostic technique for particle sizing has a wide range of practical applications. It can be used for the diagnostics of spherical and non-spherical particles present in flue gas streams, coal-water slurries, soot conglomerates, fly ash, and combustion generated particles. The success of this instrument will be very beneficial to the Nation and will allow the commercial sector to adhere to the stringent regulations of the Clean Air Act.

19

A Ceramic Material and Process for Use in Monolithic Ceramic Cross-Flow Filters--Blasch Precision Ceramics, Inc., 580 Broadway, Albany, NY 12204-2802; (518) 436-1263
Mr. David A. Larsen, Principal Investigator
Mr. David W. Bobrek, Business Official
DOE Grant No. DE-FG02-94ER81718
Amount: $617,274

Ceramic cross-flow filters are designed to provide high temperature, high pressure removal of particulates from hot gas streams in coal fueled power systems with the benefit of high surface area per unit volume. An important need has been identified for a one-piece monolithic ceramic cross-flow filter, rather than the present segmented filter that has been known to delaminate or separate in service. This delamination allows particulates to by-pass the filter, which can lead to costly damage to downstream turbines and subsequent failure to meet environmental regulations pertaining to stack gas emissions. Further, an effective hot gas stream filtration system is expected to result in greater use of plentiful coal and conservation of other less abundant fossil fuels. Current ceramic technology has proved incapable of forming such a complex one-piece shape with an acceptable permeable porous ceramic material. A unique injection mold ceramic forming process has commercially produced complex shapes of this nature for many years, but of a nonpermeable ceramic. In Phase I feasibility was demonstrated for using this process on a laboratory scale to form permeable, porous ceramic shapes of new compositions targeted to meet the filtration requirements of ceramic cross-flow filters. In Phase II the ceramic composition data and laboratory scale process techniques established in Phase I will be used as the basis for prototype production of full size one-piece monolithic ceramic cross-flow filters. Also, these prototypes will be subjected to filtration testing followed by post-test characterization. This monolithic ceramic cross-flow filter technology is expected to result in a much more effective hot gas stream filtration system for coal-fueled power stations.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase II results will determine manufacturability and filtration performance of the prototype full size monolithic ceramic cross-flow filters made in Phase I. The commercial application for this technology is hot gas stream particulate filtration for various types of coal-fueled power systems.

20

An In-Situ Microanalysis of Coal Flyash: Quantitative Correlation of Organic Surface Chemistry and Particle Composition---Charles Evans and Associates, 301 Chesapeake Drive, Redwood City, CA 94063-4723; (415) 369-4567
Dr. Jang-Jung Lee, Sr, Principal Investigator
Mr. James E. Plank, Business Official
DOE Grant No. DE-FG03-94ER81725
Amount: $748,242

The adverse effects of airborne particulates on the health of the environment and individuals have been well documented. One of the most widely studied types of pollutant particles, coal flyash, is composed of a complex mixture that encompasses a broad range of particle compositions, sizes, and morphologies. During the coal combustion process, flyash particles can absorb organic compounds, including polycyclic organic matter (POM), many of which are known to be carcinogens or mutagens. Although particle absorbed POMs have been studied using solvent extraction analysis of flyash particles, there is inadequate detection of significant heterogeneity among particles. This project will demonstrate that a Time-of-Flight Secondary Ion Mass Spectrometer (TOF-SIMS) can perform in situ organic and inorganic surface analysis of coal flyash particles. In Phase I, several POMS were successfully coated on flyash and detected on individual particles using TOF-SIMS. Phase I also demonstrated the qualitative detection of POM coverage and transformation on model flyash particulates. Phase II will extend the types of POM/flyash systems investigated and will develop quantitative correlations between particle surfaces, POM identity and surface concentration, and potential transformation reactions, especially photolysis or nitration reactions.

Anticipated Results/Potential Commercial Applications as described by the awardee: The analytical protocols developed in this research will significantly facilitate future monitoring of the chemical composition of combustion-generated particles. These analytical methods will also provide sensitive and specific chemical analysis of various airborne particles. The development of accurate organic microanalysis techniques, especially a TOF-SIMS instrument with increased sensitivity for POM detection may also lead to the development of specialized instrumentation for this type of characterization. The market for this instrumentation is in environmental clean-up and monitoring industries, and the ultra clean manufacturing industries such as the semiconductor industry.

21

Flue Gas Cleanup Using a Novel Corona Generator--Environmental Elements Corporation, 3700 Koppers Street, P.O. Box 1318, Baltimore, MD 21203; (410) 368-7239
Dr. Paul L. Feldman, Principal Investigator
Dr. Paul L. Feldman, Business Official
DOE Grant No. DE-FG05-94ER81761
Amount: $741,903

The use of a corona discharge to initiate gas phase chemical reactions leading to the chemical conversion of air pollutants is well known. Corona discharges have demonstrated the oxidation of sulfur dioxide, nitrogen oxides, and many organics effectively. The important differences among the various corona generation techniques are the amounts of energy which must be supplied per molecule oxidized. This energy requirement per unit of pollutant oxidation can differ greatly, and only the lowest energy users within this technology group have a chance of competing with commercially available technology. Maximum energy efficiency can be obtained by providing good spatial uniformity of free electrons within the corona reactor volume; then, uniform exposure and treatment of the flow through gas is assured. In Phase I, a unique corona reactor was designed in which the corona was generated uniformly, and its performance was demonstrated. The spatially distributed corona discharge, produced by the reactor operating at a low power level and short residence time, yielded a high level of mercury vapor oxidation. Phase II will implement design improvements for enhanced reliability and energy efficiency, and demonstrate the operation of a prototype commercial scale module. The prototype unit will be tested, the influence of flue gas conditions will be quantified, and the electrical energizing will be optimized.

Anticipated Results/Potential Commercial Applications as described by the awardee: If mercury control regulations are promulgated for coal burning power plants, the corona discharge technology can potentially save the U.S. utility industry and electricity consumers up to 250 million dollars per year, based upon an annual coal consumption of 720 million tons. In addition, the corona discharge technology may be the only effective technology for high temperature removal of mercuric chloride.

22

Simultaneous Hot Desulfurization and Improved Filtration in Coal Utilization Processes--
Industrial Filter and Pump Manufacturing Company, 5900 Ogden Avenue, Cicero, IL 60650-3888; (708) 656-7800
Mr. Paul Eggerstedt, Principal Investigator
Mr. Jeffrey Burgeson, Business Official
DOE Grant No. DE-FG02-94ER81786
Amount: $750,000

Much of America's vast coal reserves will remain unusable until technology capable of the effective, economical removal of particulate and sulfur emissions becomes more highly developed. In recent years, ceramic filtration devices have shown that particulate removal levels well within the limits of New Source Performance Standards (NSPS) can be achieved at high process temperatures, thereby enhancing the overall performance and efficiency of processes such as the integrated gasification combined cycle and pressurized fluidized bed combustion. Unfortunately, removal of the high levels of sulfur indigenous to much of our Nation's coal reserves has been problematic, requiring exotic, expensive sorbents, substantial coal feed pretreatment, or a significant reduction in off-gas temperature to achieve acceptable sulfur emissions. Many researchers are aware that metal oxide sorbents can be used to effectively reduce sulfur emissions in such processes. In Phase I, significant sulfur removal capacities were obtained using classified, spent metal oxides. Such materials are generated in tremendous volume as a result of metal processing, smelting, and refining operations, and are generally available at little if any cost. In particular, waste oxides of tin and zinc were among the spent metal oxides that exhibited a strong affinity for sulfur capture in oxidizing and reducing atmospheres. Phase II will use thermogravimetric analysis to verify the sorbent capacity of these two candidate waste materials. Their additional capability as a high temperature filter aid will also be determined. In combination with ceramic filtration technology, these spent metal oxides will provide sulfur dioxide (SO_2) removal and enhanced filter performance in a cost-effective manner.

Anticipated Results/Potential Commercial Applications as described by the awardee: By combining the sorbency and filter capability of metal oxides with existing ceramic filtration technology, both particulate and SO_2 contaminants will be removed in a cost-effective manner. The availability of the spent metal oxides and the minimal processing required will allow this technology to be quickly developed and permit utility companies to make use of our Nation's high sulfur coal reserves while meeting existing emissions regulations.

23

Development of Expansive Cements Using Dry Flue Gas Desulfurization (dFGD) Solid Wastes--
Praxis Engineers, Inc., 852 North Hillview Drive, Milpitas, CA 95035-4544; (408) 945-4282
Mr. Steven R. Hadley, Principal Investigator
Ms. Suzanne C. Shea, Business Official
DOE Grant No. DE-FG03-94ER81832
Amount: $748,476

Dry flue gas desulfurization (dFGD) is an emerging advanced sulfur dioxide (SO_2) control system for pulverized coal-fired power plants with an estimated worldwide generating capacity of 20,000 MW. In this system, calcium hydroxide is used to capture the $S0_2$ in the flue gas. The resulting by-product is combined with the fly ash for disposal. However, the presence of substantial amounts of sulfur compounds and unreacted calcium hydroxide in the fly ash suggests the possibility of using this material to make expansive cements. The feasibility of doing so was successfully demonstrated in Phase I. High-quality expansive cements were produced in which dFGD fly ash replaced nearly half of the ordinary Portland cement used conventionally. This led to a cost advantage of nearly $25/ton. The performance of the dFGD-based cements exceeded ASTM requirements for compressive strength and restrained expansion. The main focus of Phase II will be on producing and testing expansive cements, mortars, and concretes from dFGD fly ash. However, Phase I also indicated that dFGD cements can be used in high-performance concrete and as replacements for ordinary cements in certain applications. This will greatly enhance their market share. The result of this effort will be a technology which can convert a waste product into high-quality expansive cements.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated result of this project is development of high-quality expansive cements from dFGD fly ashes. Three important benefits would result. First, the cost of landfill disposal of dFGD solid waste will be eliminated. Second, the energy cost for production of cement will be lowered because the addition of dFGD fly ash does not require the high-temperature processing and grinding used to produce conventional Portland cement. Third, the utilization of dFGD fly ash will reduce the mining requirements for cement kiln feed materials, thereby reducing the associated environmental impacts. The main benefits thus are both environmental and economic. Utilities that use dFGD technology will benefit greatly from this development. The technology also has potential markets in Europe and Asia.

24

Ultrasensitive In-Situ Detection of Toxic Flue Emission--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143-4228; (617) 547-1122
Dr. Allen Flusberg, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-94ER81855
Amount: $749,992

The 1990 Clean Air Act Amendments list nearly two hundred toxic materials that must be regulated. Among these are polycyclic aromatic hydrocarbons (PAHs), carcinogens that are associated with incomplete combustion of fine particulates. There is a need for new technology to measure very low concentrations of PAHs located at sites adjacent to coal-fired utilities. Extractive methods are expensive and are not applicable to continuous, in-situ monitoring of the concentrations of these toxic emissions. The goal of this project is to development an instrument called a tunable pulsed absorption diffractometer (TPAD). This instrument will detect a transient, volumetric diffraction grating that is formed after a pulsed laser beam is absorbed by toxic emissions present in the illuminated region. A TPAD can be tuned through the near-infrared absorption spectrum of PAHs to determine their concentration in the presence of other absorptive species. Phase I demonstrated feasibility by (1) matching a commercially available pulsed laser with the absorption spectrum of PAHs, (2) demonstrating the diffractometer concept in an experiment that was in excellent agreement with theoretical predictions, and (3) designing a proof-of-principle demonstration of detecting ng/m^3 levels of PAHs. Phase II will include the construction and testing of a laboratory TPAD, the demonstration of the sensitivity of a TPAD to various gaseous species including PAHs generated in incomplete combustion, and the design of a prototype brassboard TPAD.

Anticipated Results/Potential Commercial Applications as described by the awardee: The TPAD will be an essential tool for monitoring real-time, in-situ toxic PAH emissions in the vicinity of coal-fired power plants, industrial sources of pollution, and heavy automobile traffic.

ADVANCED TECHNOLOGY FOR THE RECOVERY, STORAGE, AND UTILIZATION OF NATURAL GAS

25

Landfill Gas Conversion to a Contaminant-Free Methane-Carbon Dioxide Reformer Feedstock for Methanol Synthesis---Acrion Technologies, Inc., 9099 Bank Street, Cleveland, OH 44125; (216) 573-1187
Dr. William R. Brown, Principal Investigator
Dr. William R. Brown, Business Official
DOE Grant No. DE-FG02-94ER81690
Amount: $750,000

Landfill gas (LFG) is roughly an equal mixture of methane (CH_4) and carbon dioxide (CO_2) which becomes contaminated with many volatile trace compounds as it migrates through the landfill. LFG collection systems are installed primarily to prevent off-site migration and to control odors; an indirect benefit is the reduction of greenhouse gas emissions. Most collected LFG is simply flared to convert CH_4 to CO_2, a nonexplosive, nontoxic, less potent greenhouse gas. The purpose of this project is to demonstrate the recovery of raw LFG as a contaminant-free mixture of CH_4 and CO_2 to serve as reformer feedstock for methanol synthesis. No hazardous solvents or other separating agents will be used, and CO_2, an environmentally benign "green" solvent condensed directly from LFG, will be used as a cold absorbent to remove LFG contaminants below parts per million levels. In Phase I, the ability of liquid CO_2 to absorb LFG contaminants was confirmed. A pilot scale absorption column was used to measure the absorption of six contaminants: dichlorodifluoromethane (Freon-12), methyl chloride, acetone, pentane, ethanol, and ethylene dichloride. Gas phase contaminant concentrations were reduced by factors ranging from 100 to 5000, often to levels below the detection limit of the analytical equipment. These results show that Freon-12 and methyl chloride, the most volatile chlorinated compounds, and therefore the most difficult to remove from LFG, can be reduced to levels which will not poison methanol synthesis catalysts. Phase II will demonstrate the production of contaminant-free, methanol-synthesis feedstock gas from raw LFG by contaminant absorption with cold liquid CO_2.

Anticipated Results/Potential Commercial Applications as described by the awardee: Applications include acid gas removal from gases containing large amounts of CO_2 such as from the partial oxidation of coal or heavy hydrocarbons, low quality natural gas, and Claus sulfur plant tail gas. Methanol from LFG provides a renewable liquid transportation fuel for use as a gasoline additive, as fuel, or converted to methyl tertiary butyl ether. Contaminant absorption with liquid CO_2 has wide applicability in gas processing.

26

Forecasting Reservoir Thickness with Fractals--Correlations Company (formerly NW Resources), P.O. Box 187, Socorro, NM 87801-0187; (505) 835-5220
Mr. Trent Boneau, Principal Investigator
Mr. Bill Weiss, Business Official
DOE Grant No. DE-FG05-94ER81821
Amount: $750,000

The application of the mathematical fractal theory to the estimation of reservoir thickness in an actual gas reservoir has indicated that the prediction of low net pay thickness can be avoided when drilling infill wells. Culmination of the Phase I tasks suggest that a fractal based predictive method could save the Nation's domestic producer $1,000,000,000 per year. Advancing this new fractal mapping technology to the point where it is readily available to the Nation's gas and oil industry is the objective of this proposal. The major effort of Phase II is the development of a commercial software which will include the fractal approaches developed in Phase I and Phase II. In Phase II, the fractal approach developed in Phase I will be extended to include field spatial correlations by automatically matching the fractional noise variogram. The resulting fractal mapping methods will be tested on various geologic depositional environments and compared to other deterministic and stochastic mapping methods with various depositional environments. The market assessment accomplished during Phase I, indicates that commercial software must include other deterministic and geostatistical methods. Hence, additional mapping methods will be coded in a professional manner and included along with the fractal methods in the commercial software. Emphasis will be given to develop fast algorithms using modern mathematical liberties, and high quality graphical representation of each mapping technique.

Anticipated Results/Potential Commercial Applications as described by the awardee: The computer tools developed during Phase II will be especially useful to petroleum technicians charged with the continued development of the nation's natural gas reservoirs. Upon completion of Phase II, the computer code will be promoted through the information Super Highway and made available through conventional commercial channels.

27

A Membrane Reactor for the Spontaneous Conversion of Natural Gas and Carbon Dioxide Mixtures into Valuable Feedstock--Eltron Research, Inc., 2830 Wilderness Place, #E, Boulder, CO 80301-5455; (303) 440-8008
Dr. Michael Schwartz, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG02-94ER81748
Amount: $749,592

This project is directed at developing catalytic membrane reactors compatible with promoting the spontaneous and highly selective oxidative reforming of carbon dioxide/natural gas mixtures to synthesis gas. Hence this technology will spontaneously convert two greenhouse gases into valuable feedstock for subsequent conversion to methanol or gasoline. These membranes behave as short circuited electrochemical cells with both ionic and electronic transport proceeding through the membrane bulk. Work performed during Phase I identified brownmillerite oxygen anion and electron conducting membranes and surface catalysts for promoting this reaction with high selectivity and rates under conditions where net carbon dioxide consumption occurred. Phase II consists of (1) selecting preferred brownmillerite mixed conducting membranes and surface catalysts for the carbon dioxide/natural gas oxidative reforming surface, (2) performing an in-depth study of catalytic membrane performance aimed at component optimization, (3) developing and optimizing fabrication techniques for tubular membrane reactors, and (4) fabricating multi-tube catalytic membrane reactor stacks which will be subjected to extensive performance testing. Application of mature technology will be expected to be both simple and inherently of low cost, and should circumvent many of the conversion efficiency restrictions currently limiting conventional natural gas steam reforming technology.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of Phase II will result in characterizing a catalytic mixed conducting membrane technology compatible with the spontaneous conversion of carbon dioxide/natural gas mixtures into synthesis gas at both practical rates and high selectivity. Since synthesis gas is a widely used chemical industry feedstock this technology will be of significant economic and technical benefit to the Nation by lowering the cost of methanol, liquid fuel oxygenates, and gasoline all of which can be derived from this precursor.

28

Tubular Catalytic Membrane Reactors for the Spontaneous Conversion of Humidified Natural Gas to Synthesis Gas--Eltron Research, Inc., 2830 Wilderness Place, #E, Boulder, CO 80301-5455; (303) 440-8008
Dr. Anthony F. Sammells, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG02-94ER81750
Amount: $749,998

This project is directed towards developing tubular catalytic membrane reactors to promote spontaneous conversion of humidified natural gas to synthesis gas at rates suitable for commercialization. The approach uses heat generated by the exothermic methane partial oxidation reaction to drive the endothermic steam reforming reaction. This will result in lowering the cost of producing synthesis gas by 30 to 50%, resulting in a reduction of methanol production costs by 15 to 25% using this feedstock. In Phase I, the project identified oxygen anion and electron conducting ceramic membranes and surface catalysis for promoting this reaction at high rates, and with desired product composition and high selectivity. Phase II will by (1) identify preferred mixed conducting membrane constituents and promoting catalysts for the spontaneous humidified natural gas oxidative reforming reaction, (2) address catalytic membrane reactor component optimization from systematic performance evaluation, (3) develop and optimize fabrication techniques for tubular membrane reactors, and (4) fabricate multi-tube catalytic membrane reactor stacks and subject them to extensive performance testing.

Anticipated Results/Potential Commercial Applications as described by the awardee: The project will result in characterizing a catalytic mixed conducting membrane technology compatible with the spontaneous conversion of humidified natural gas to synthesis gas at practical rates with desired product composition, high selectivities, decreased energy consumption, and minimal environmental impact. Since synthesis gas is a widely used chemical industry feedstock, this technology will be of significant economic and technical benefit to the Nation by lowering the cost of methanol, liquid fuel oxygenates, and gasoline, all of which can be derived from this precursor.

29

A Multi-Functional Component to Simplify Fuel Cell Power Plants--Energy Research Corporation, 3 Great Pasture Road, Danbury, CT 06813; (203) 792-1460
Mr. Andrew Skok, Principal Investigator
Dr. H. C. Maru, Business Official
DOE Grant No. DE-FG05-94ER81756
Amount: $749,962

Electrochemical conversion of natural gas, coal gas, biofuels and other hydrocarbon fuels by carbonate fuel cells is an attractive option for future power generation. Present generation carbonate fuel cell power plants are complex, using a carbon dioxide recycle, a variable-Btu burner, a fuel pressure booster, a start-up burner, and in some cases, a cathode recycle hot blower. Its commercial potential can be improved by simplifying the baseline fuel cell system design. This project aims at the design, building, and testing of a multi-functional component (MFC) in conjunction with a multicell stack. In Phase I, the concept of a single multi-functional component which performs all the above duties was developed. The technical feasibility of the MFC concept and its integration with a fuel cell module was established, and the design requirements were identified. Phase II will design, build, and verify the operability of this integrated component in conjunction with a multicell stack which would culminate in a MFC test with a 5 kW-class stack. This novel component opens up significant opportunities for power plant design simplification by consolidating several items of process equipment into one and eliminating associated hot piping. Use of this component in a fuel cell power plant will result in process equipment footprint reduction by 30% and elimination of 70% of hot process piping.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned MFC concept is anticipated to simplify the carbonate fuel cell power plant and improve its operability. A significant reduction in cost of up to $150/kW in the system is anticipated. This concept should improve the commercial potential of carbonate fuel cell power plants and offer an exceptional opportunity for providing economically competitive, highly efficient, low emissions power generators for utilities, industrial, and commercial cogenerators. The MFC concept may also be used for defense applications as well as for other types of fuel cell power plants.

30

Cost Effective Stimulation of Shallow Oil and Gas Wells Using High Energy Gas Fracturing Fielded Without a Wireline or Workover Rig—
J Integral Engineering, 165 Southwest Tualatin Loop, West Linn, OR 97068-9733; (503) 557-1370
Dr. Richard A. Schmidt, Principal Investigator
Dr. Richard A. Schmidt, Business Official
DOE Grant No. DE-FG03-94ER81791
Amount: $748,977

Current models and data show that high energy gas fracturing (HEGF) has great potential as a stimulation tool in shallow oil and gas wells. In these wells, the in-situ stresses are sufficiently low for the process to generate adequate gas volumes and to create an effective multiple fracture network. To address this opportunity, HEGF techniques must be simplified and costs reduced to allow oil and gas production without resorting to chemical treatment, hydraulic fracturing, or the drilling of new wells. In Phase I, the new HEGF tool was designed using a concept that eliminates the need for wireline, slick line, tubing, or any other support equipment. It also eliminates the problem of wireline damage so often experienced in HEGF treatments. In Phase II, well tests will be conducted before and after each treatment to evaluate changes in each well's ability to transmit fluids to and from the wellbore. Three different propellant formulations will be evaluated in each formation in order to correlate gas burning characteristics with stimulation performance as a function of rock type and well depth. The result will be a data base that can be used to validate analytical and empirical models and to optimize HEGF treatments for maximum effectiveness.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful field trials of the new HEGF technique will provide the oil and gas industry with an advanced, cost-effective method of stimulating the production of many thousands of wells that would not previously have been considered candidates for economic reasons. Wells that will benefit include: low production stripper wells, wells in naturally fractured reservoirs, gas storage wells, and injection wells used in waterfloods and other enhanced recovery processes.

31

Membrane Module Development for a Natural Gas Dehydration Process--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025-1516; (415) 328-2228
Dr. Hans Wijmans, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-94ER81807
Amount: $750,000

All natural gas must be dehydrated before entering the national distribution pipeline. Currently glycol absorption dehydrators are widely used, and approximately 30,000 units are in service. However, glycol dehydrators are not well suited for use on small gas streams or on offshore platforms, increasingly common sources of natural gas. In addition, these units coextract benzene, a known carcinogen and trace contaminant in natural gas, and release the benzene to the atmosphere. EPA has announced its intention to require benzene emission control systems to be fitted to many of these glycol units. Membrane processes are an alternative approach to natural gas dehydration. In Phase I, high flux, high selectivity membranes were fabricated into an innovative module design. Bench scale modules were used to dehydrate synthetic natural gas at pressures up to 1,000 psig. The new module design was able to control concentration polarization on the feed side of the membrane which is a major problem in this type of separation. The module also operated in a counterflow mode. These modules had three times the flux and one-half of the methane loss of the best current commercial membrane modules. An economic analysis showed that systems using these membrane modules would be significantly less expensive than glycol dehydration units for all flows less than 15 million standard cubic feet per day (MMscfd). In Phase II, the development and demonstration of this new membrane based natural gas dehydration process will be completed. The process will be scaled to the demonstration stage and a system will be built containing 8-inch diameter modules.

Anticipated Results / Potential Commercial Applications as described by the awardee: The membrane dehydration process to be developed in this project will be less expensive than glycol dehydration systems for all plants smaller than 15 MMscfd. The absence of rotating equipment, the small size, the low weight, the absence of open flames, and the elimination of benzene emissions are other operational advantages that are sought by the industry.

32

Continuous Pressure Swing Adsorption (CPSA) for Nitrogen Rejection from Natural Gas--Northwest Fuel Development, Inc., 4064 Orchard Drive, Lake Oswego, OR 97035-2406; (503) 699-9836
Dr. Peet M. Soot, Principal Investigator
Dr. Peet M. Soot, Business Official
DOE Grant No. DE-FG03-94ER81819
Amount: $750,000

Nitrogen rejection continues to be the major technological and economic hurdle for producing pipeline quality gas from low-quality gas resources. Numerous types of processes have been proposed for nitrogen rejection, but pressure swing adsorption is one of two that have been technically demonstrated. Unfortunately, it has not been proven economically competitive. This project involves exploration of the technical and economic viability of a continuous pressure swing adsorption (CPSA) process. In Phase I, it was demonstrated that activated carbons (AC) and zeolites can effect the desired separation of nitrogen from methane. A significant discovery during Phase I was that 4Å zeolites exhibited nitrogen selectivity in the process because of the kinetics of nitrogen versus methane adsorption. This provides the potential option of using either a methane-selective adsorbent, AC, or a nitrogen-selective adsorbent, 4Å zeolite, in the CPSA process. Even though the simple CPSA cycle is constrained in its upgrading capabilities, the addition of process engineering unit operation enhancements provides the potential for upgrading a wide variety of sub-quality gases to pipeline quality natural gas. In Phase II, a demonstration plant will process 300 MCFD (thousands of cubic feet per day) of feed gas, which at this small scale, can cost less than one dollar per MCF of product. The building of a larger plant, capable of producing three million cubic feet per day of pipeline gas, could have a processing cost of only $0.48/MCF of product.

Anticipated Results / Potential Commercial Applications as described by the awardee: The Nation has nearly 250 trillion cubic feet of sub-quality natural gas. Successful development of this process should provide economic, national security, and environmental benefits. Cost estimates show that this process can provide gas at lower prices than current levels and uses a domestic resource. Environmental benefits also arise from the capture of methane, a greenhouse gas.

33

Removal of Hydrogen Sulfide from Natural Gas by Electron Beam Irradiation--Science Research Laboratory, Inc., 15 Ward Street, Somerville, MA 02143-4228; (617) 547-1122
Dr. Henry Eppich, Principal Investigator
Dr. Jonah Jacob, Business Official
DOE Grant No. DE-FG02-94ER81853
Amount: $749,994

Natural gas represents 20% of the primary energy resources of the United States and accounts for almost half the energy consumed for residential heating. Eighteen percent of the natural gas reserves in the Nation are not usable because they contain more than four parts per million (ppm) of hydrogen sulfide (H_2S). This corresponds to 19 trillion cubic feet (TCF) of the known reserves. Studies estimate that 80 TCF of the undiscovered natural resources are also contaminated with unacceptable concentrations of H_2S. Natural gas contaminated with H_2S is an environmental hazard because of its toxicity and the sulfurous compounds produced and released during combustion. In addition, it is corrosive to pipeline systems. Current technologies for H_2S removal rely on disposable sorbents or are complex; costs are between 20 and 26 cents per thousand standard cubic feet (MSCF). This cost is almost independent of the amount of H_2S in the natural gas. In Phase I, electron beam radiolysis was demonstrated that efficiently dissociated H_2S in methane/H_2S mixtures. Based on these results, it was estimated that the electron beam process, combined with a confined vortex scrubber, would purify natural gas containing 1000 ppm of H_2S for seven cents/MSCF. This is a factor of three less expensive than existing methods; moreover, the cost for the electron beam process would decrease to 0.9 cents/MSCF for natural gas containing only 100 ppm. In Phase II, engineering issues will be addressed to insure reliable operation of the electrostatic accelerator based sweetening process. In addition Phase II will demonstrate that this electron beam/confined vortex scrubber sweetening concept is a cost effective integrated process for removing H_2S from natural gas.

Anticipated Results / Potential Commercial Applications as described by the awardee: Along with cost effective H_2S removal, other important applications include control of stack gas emissions, natural gas dehydration, direct scrubbing of H_2S from natural gas using amine solutions, removal of aerosols from natural gas flows, bulk sterilization of disposable medical products, and clean-up of water contaminated with hydrocarbons.

COAL-BASED POWER SYSTEMS TECHNOLOGY

34

High Temperature Brazing of Silicon Carbide--Busek Company, Inc., 11 Tech Circle, Natick, MA 01760-1023; (508) 655-5565
Dr. V. Hruby, Principal Investigator
Mrs. J. Budny, Business Official
DOE Grant No. DE-FG02-94ER81721
Amount: $748,282

Silicon carbide has a unique set of properties that make it ideally suitable for use in high temperature energy conversion devices. Its use is currently impeded by lack of reliable techniques for joining silicon carbide (SiC) to metals. The effort carried out in Phase I and to be continued in Phase II is designed to overcome this impediment. The objectives of Phase I were met and in some areas significantly exceeded. The feasibility of SiC (Hexoloy SA) brazing to various metals for high temperature service was successfully demonstrated. Hexoloy is wetted by active and nonactive filler metals if the SiC surface is appropriately conditioned prior to brazing. Brazed joints whose strength exceeds that of the bulk ceramic were demonstrated. To date Hexoloy has been brazed to Haynes 230, SST 304, Kovar, W/Cu (75/25) and molybdenum. Phase II will continue the development of SiC-to-metal joints using active filler metals for intermediate temperatures (~1000°C), and will create an SiC brazing database. Because of the potential for brazed joint degradation in long term, high temperature service (>650°C) by active braze elements, a new high temperature (≥1100°C) brazing technique for SiC will be demonstrated. The technique rests on a novel SiC surface conditioning method which forms an impervious barrier at the SiC/filler metal interface. As a result SiC-to-metal and SiC-to-SiC high temperature joints of the same strength as the bulk material will be demonstrated. The joints with metals including Incoloy 909, titanium, and molybdenum will be strength tested at elevated temperatures up to 650°C. Residual stresses in the SiC-to-metal joints will be mitigated with the use of a novel compliant layer. SiC tube-to-metal tube joints will be brazed using the new technique and tested in two current applications pertinent to power generation, liquid fuel production, and aircraft jet engines.

Anticipated Results/Potential Commercial Applications as described by the awardee: Simple estimates of SiC benefits facilitated by the proposed research just in one application, natural gas based power generation, indicate potential annual savings exceeding a billion dollars. Similar payoff can be expected in the emerging area of SiC power semiconductors which must have brazed multiple metallic terminals. The largest market for such semiconductors capable of operating at 500°C is in the transportation industry, principally the electric and/or hybrid automobile.

35

A Long Life Zinc Titanate Sorbent--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033-1916; (303) 940-2301
Dr. Robert J. Copeland, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-94ER81881
Amount: $750,000

Coal-fired gasifier combined cycles (GCC) have both high efficiency and very low emissions. A critical need for GCCs is a method of removing the hydrogen sulfide (H_2S) produced from the sulfur in the coal from the hot gases. There has been extensive research on hot gas clean-up systems, focused on the use of a zinc oxide based sorbent (e.g., zinc titanate). Unfortunately, current sorbents are relatively expensive; a low-cost sorbent which also has a long life is needed. A new method of producing sorbent pellets with greatly increased lifetimes has been developed. During Phase I it was shown that the sorbent can have a long life and remain active. One formulation had a high sulfur capacity but has limited crush strength. Another formulation had a high attrition resistance and high crush strength but a lower sulfur capacity. While both formulations show some promise, additional work is needed to optimize formulation and demonstrate the advantages of the new sorbent. During Phase II, the sorbent composition will be modified to provide both high sulfur capacity with high attrition resistance while maintaining the long life capacity. The first portion of the project will develop and screen these formulations. Multiple cycle (i.e., 100 cycles) testing of one sorbent will be conducted.

*Anticipated Results/Potential Commercial Applications*as described by the awardee: This new method of producing the sorbent will reduce the cost of hot gas cleanup of H_2S by increasing the life and decreasing the cost of the zinc oxide sorbent. The new method may be applicable to other absorbent applications. The low-cost, long-life sorbent will reduce the cost of hot gas cleanup H_2S sorbents and improve the economics of GCC.

ROBOTS FOR NUCLEAR ENVIRONMENTS

36

A Low Cost Infrared Sensor Based System for Robotic Welding--Weld Star Technology, Inc., 8204 Gondola Drive, Orlando, FL 32809-6735; (334) 887-5886
Mr. Wing Y. Chin, Principal Investigator
Mrs. Teresa S. Chin, Business Official
DOE Grant No. DE-FG05-94ER81899
Amount: $750,000

Nondestructive testing, identification, and repair of weld defects have been shown to consume as much as 25% of the total weld production cost in pipelines, ship fabrication, and power generating systems. Infrared sensor-controlled welding systems have been demonstrated that would greatly reduce or eliminate expensive, after-the-fact nondestructive testing and weld repair. However, the cost of these systems has been well over $60,000; hence, commercialization of this technology has not occurred. This project is developing an infrared sensor-based system for weld process control which will cost nearly $8,000 less than current systems. This cost would place this new technology well within the reach of pipeline, ship, and heat transfer piping fabricators. In Phase I, three low cost infrared sensor assemblies were constructed. The sensor assemblies were able to identify changes in the depth of weld penetration for stepped and gradually increasing thickness plates. The total system response speed was determined to be adequate for controlling weld penetration at speeds of up to 10 inches per minute. Weld penetration and microstructural control were successfully demonstrated with a portable personal computer. In Phase II, the low cost infrared sensor penetration control welding system will be developed and commercialized.

Anticipated Results / Potential Commercial Applications as described by the awardee: This low cost, infrared sensor-based weld control system will greatly improve the quality and productivity of the welding process by enabling control of weld penetration depth and microstructure. Significant decreases in costs of weld production, nondestructive examination, and weld rework are anticipated for construction and repair of nuclear and fossil energy piping, oil and gas pipelines, double hull oil tanker ships, and storage vessels.

TECHNOLOGY FOR SPACE NUCLEAR PROPULSION AND POWER

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An Infrared Bandpass Thermophotovoltaic Filter Production Process--EDTEK, Inc., 14704 Southeast 100th Street, Renton, WA 98059-3750; (206) 235-5163
Mr. William E. Horne, Principal Investigator
Mr. William E. Horne, Business Official
DOE Grant No. DE-FG03-94ER81742
Amount: $749,999

A recent development in infrared (IR) bandpass filters for thermophotovoltaic (TPV) applications has made TPV power production practical by employing the Department of Energy general purpose heat sources (GPHS) as a source of IR energy. These filters either transmit or reflect energy with broad band absorption less than about one percent. Thus, the parasitic losses in TPV systems can be reduced to a very low level even with blackbody emitters. During Phase I, the feasibility of ion beam lithography (IBL) as a low-cost filter production process was demonstrated. The production process reduces the filter cost to less than $\$1.00/\text{cm}^2$ and improves the performance and quality control of the filters. Phase II will (1) continue research to optimize the IBL production process including extending the lifetime of IBL stencil masks, a vital step for cost effective, large scale processing, (2) design and assemble a pilot production line and document the production process, (3) demonstrate the operation of the pilot production capability via the fabrication of large area IR mesh filters on a prototypical basis, and (4) optimize the performance of production IR bandpass TPV filters for use in a radioisotope-fueled TPV power system. The resultant pilot production line will have sufficient capacity to supply the filter needs of small, radioisotope TPV power supplies required for planned, near-term space missions. The pilot line will also provide the experience base for deploying a full production line to supply the needs of terrestrial TPV power systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The result of the planned effort will be a low-cost production process capable of manufacturing IR bandpass TPV filters to meet near term demands of both space and terrestrial TPV applications. These filters will raise the efficiency of TPV conversion substantially. Applications are expected in radioisotope, nuclear, solar, and gas fired electric power generators. The applications range from space probes to recreational vehicles.

38

High Temperature Thermally Stable Multi-Layer Quantum Well Films--Hi-Z Technology, Inc., 6373 Nancy Ridge Drive, San Diego, CA 62121-2247; (619) 535-9343
Mr. Norbert B. Elsner, Principal Investigator
Mr. Norbert B. Elsner, Business Official
DOE Grant No. DE-FG03-94ER81777
Amount: $750,000

Previous studies of silicon/silicon germanium (Si/SiGe) multi-layer quantum well films have shown very encouraging thermoelectric properties near room temperature and below. Above 400 K however, no improvement over bulk SiGe has been noted and, if improved higher temperature films could be developed, they might degrade because of inter-diffusion of the Si, SiGe, and the dopants. New compounds were investigated that are known to exhibit little diffusion at 1,100°C. In Phase I angstrom-thickness films were made of this material, and their thermoelectric properties were evaluated. The power factor values (i.e., Seebeck coefficient^2/resistivity: $\propto^2/\rho$) of these films were measured to be around 500 µW/cm-°C^2 which is more than an order of magnitude higher than that of SiGe at room temperature. The $\propto^2/\rho$ values also improve significantly in heating to 1,100°C. Similar increases in $\overset{2}{Z}(=\propto/\rho\kappa)$ will be realized if the thermal conductivity (κ) of these films is the same as that of the materials in bulk form. Use of these films in a space generator should improve the system efficiency more than 17%. Phase II will build up these films to thick enough levels so that all of their thermoelectric properties can be evaluated as a function of temperature by themselves and free of a substrate. In Phase II it is also planned to build a thermoelectric device consisting of both N-type (negative) and P-type (positive) legs and to demonstrate the conversion efficiency which is expected to be much improved compared to currently available thermoelectric devices.

Anticipated Results/Potential Commercial Applications as described by the awardee: Use of these films is very encouraging for doubling the efficiency of present thermoelectric modules that are used in remote power supplies and for converting waste heat into electricity. This large increase in module performance should lower the cost/watt by half and open up many more commercial opportunities for recovering waste heat from vehicles, furnaces, fuel cells, etc. A more than billion dollar waste heat recovery industry remains to be developed, especially with exports, since the cost of fuel is three to five times higher outside the United States.

TECHNOLOGY TO SUPPORT AND IMPROVE NUCLEAR FUEL CYCLE PROCESSES

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A Long Life Perovskite Oxygen Electrode for Calcium and Lithium Oxide Processing in Nuclear Fuel Cycles---Eltron Research, Inc., 2830 Wilderness Place, #E, Boulder, CO 80301-5455; (303) 440-8008
Dr. Anthony F. Sammells, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG02-94ER81751
Amount: $749,994

This project is directed towards developing electrolytic technology incorporating long-life anode electrocatalysis for oxygen evolution in cells used for promoting either calcium (Ca) or lithium (Li) oxide splitting from molten halide salts. This technology development complements current ongoing investigations involving pyrochemical processes directed towards the recovery of uranium and transuranium elements present in spent fuel originating from light water reactors. Phase I demonstrated rapid electrode kinetics for the oxygen evolution reaction and unequivocally showed viability for achieving long-life, non-consumable oxygen anodes in the electrolytic splitting of metal oxide-containing molten salts. Phase II will address (1) selecting preferred electrolytic cell components and anode electrocatalysts for promoting the electrolytic splitting of metal oxides, (2) performing an in depth study of electrolytic cell performance aimed at component optimization, (3) developing and optimizing fabrication techniques for prototype electrolytic cells, and (4) fabricating multi-cell electrolytic cell stacks which will be subjected to extensive performance testing. Application of the mature technology is expected to be simple and efficient and to circumvent many of the corrosion issues currently restricting alternative electrolytic strategies for promoting this process.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of Phase II will result in characterizing a technology compatible with the electrolytic splitting of metal oxides present within molten salts. Optimum components will provide for long-life, non-consumable oxygen electrodes in electrolytic cells. Commercial applications include (1) supplying reducing agents (Li or Ca) for the recovery of uranium and transuranium elements present in spent fuel from light water reactors, (2) refining aluminum, (3) remediation of lead from copper alloys, (4) high energy metal/oxygen batteries, and (5) refining titania, neodymia, and beryllia.

PERSONAL MONITORING FOR PARTICULATES

40

A Programmable Particulate Sampling System--Anatole J. Sipin Company, Inc., 505 Eighth Avenue, New York, NY 10018-6505; (212) 695-5706
Mr. A. J. Sipin, Principal Investigator
Mr. A. J. Sipin, Business Official
DOE Grant No. DE-FG02-94ER81705
Amount: $595,000

To provide assurance that industrial workers are not exposed to hazardous air, continuous personal monitoring is frequently performed by drawing an air sample through a particulate collection device that is worn in the breathing zone of the worker and connected through a flexible tube to a belt-mounted air pump. Currently, the procedure has several drawbacks including possible erroneous measurement caused by occlusion of the tube, a requirement for setting the flow rate before each use of the pump, and the need for frequent calibration. This project will develop an improved programmable air sampling system (PASS) that overcomes the limitations of existing devices in monitoring the concentration of particulates to which a worker is personally exposed during a work shift. In Phase I, a design and preliminary specifications covering all components of the system were generated. Endurance stability tests of experimental pump assemblies were conducted which demonstrated long term calibration

stability. Two modular systems conforming to the specifications were built. Each system comprises a separable sampler pump module, an analog control module, and a battery module and provides a usable range of flow rates. Phase II will complete the development of engineering prototypes of the PASS, which will include a microcomputerized digital control/data module and a separate programmer/ datalogger. The latter will remotely insert operating instructions and read out measured and calculated values from the digital module. Phase II will result in completely tested, pre-manufacturing PASS prototypes.

*Anticipated Results/Potential Commercial Applications*as described by the awardee: PASS will provide non-adjustable, non-accessible, tamper-proof air samplers that will save time and effort and improve data, so as to facilitate expanded surveys of exposure to particulates in Government facilities, as well as in plants and mines.

EDUCATIONAL TECHNOLOGY: ELECTRONIC GAME DEVICES FOR MATHEMATICS, SCIENCE, AND ENGINEERING

41

Computer Games to Teach Geography: El Nino: Mysteries of the Pacific and Mysteries of the Antarctic--Gautier-Downes and Associates, 2656 Montrose Place, Santa Barbara, CA 93105-2143;
(805) 682-8824
Dr. Catherine Gautier, Principal Investigator
Ms. Jeannette Gautier-Downes, Business Official
DOE Grant No. DE-FG03-94ER81770
Amount: $749,988

Two interactive educational science games: El Nino: Mystery of the Pacific and Mysteries of the Antarctic will be developed. These games are designed to be played interactively by teams in a classroom setting where role playing is required to meet the educational objectives. The educational components are based on up-to-date research topics and analysis tools using high-tech instrumentation on a simulated ocean-going research vessel. The object of the game is for players to organize and execute a scientific field experiment aimed at collecting scientific data to investigate aspects of the particular scientific topic and then analyze and publish the results. The games bring together various scientific issues and disciplines to form an integrated perspective of the Earth as a system. In Phase I, the entire El Nino game was mapped with about 15 entertaining educational modules, and a prototype was developed and tested. This prototype also allowed the determination of whether high school students like this type of approach to learning and, as importantly, whether they learn from it. Positive feedback was obtained on both issues. Phase II has two main objectives: (1) to fully develop the general framework of the development of a number of Earth System Science/Geography games and (2) to bring two games to the home and school markets which are able to run on personal computers. These games will incorporate instructional strategies and curriculum philosophies that are aligned with current reform efforts in the teaching of science (e.g., California Science Framework). To achieve these objectives, strategic alliances will be developed with the private sector, the government, and local schools, all of which have expressed a strong interest in the game.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project should result in two games which will have an enormous potential commercial application. Contacts with high school teachers suggest that they are extremely interested in such products which bring together many scientific disciplines and allow students to learn about new technologies and scientific methods (e.g., modeling Earth Processes). Aligning these games to current state and national reforms in the teaching of science will make them attractive to science educators.

42

An Intelligent Tutoring Game to Teach Scientific Reasoning--Research Development Corporation, 2875 Towerview Road, Suite A4, Herndon, VA 22071-3205;
(703) 904-1808
Dr. John M. Leddo, Principal Investigator
Dr. John M. Leddo, Business Official
DOE Grant No. DE-FG05-94ER81847
Amount: $750,000

Today's workforce requires ever increasing competence in mathematics, science, and engineering skills. Unfortunately, recent surveys suggest that U.S. students rank at the bottom of industrialized nations in scientific competence. This jeopardizes our long-term outlook for leadership in a high-tech world. Intelligent tutoring games provide individualized instructional remediation in a game setting. A detective game based on a science fiction milieu provides a fertile opportunity for teaching students to view science as an evolving process of inquiry. The project is designed to determine whether an integrated knowledge structure can adapt to the proposed curriculum objectives. Additionally, it will educate students in the concepts and procedures associated with scientific reasoning. Individualized training in critical thinking will be provided by using a proprietary automated assessment methodology. The futuristic exploratory environment is engaging to students of both sexes. It avoids lethal violence between sentient beings, while maintaining an enjoyable atmosphere. The first person perspective supports personalization of the game playing experience. The SEGA and Nintendo game machines are inexpensive enough for all socio-economic levels in the U.S. This game will support classroom as well as home learning.

Anticipated Results/Potential Commercial Applications as described by the awardee: Electronic game machines and multimedia platforms are common in the U.S. This applied research project should yield a commercially viable game and establish a marketable technology.

GREEN CAR: SCIENTIFIC APPROACHES TO AUTOMOTIVE INNOVATIONS

43

A Low Emission Alkali Metal Thermal to Electric Converter (AMTEC) Automotive Power System--Advanced Modular Power Systems, Inc., 4667 Freedom Drive, Ann Arbor, MI 48108-9784; (313) 677-4260
Dr. Thomas K. Hunt, Principal Investigator
Dr. Thomas K. Hunt, Business Official
DOE Grant No. DE-FG02-94ER81696
Amount: $749,857

The alkali metal thermal to electric converter (AMTEC) is a static energy conversion device that operates at thermal to electric conversion efficiencies that are independent of size, have reached 19%, and are expected to reach 25% to 30% soon. These systems operate silently, with no moving parts, and can utilize any source capable of delivering heat at 700°C to 900 C. Because they are as efficient as small internal combustion engines over a wide range of output (within 5% of peak efficiency from 15% to 85% of full power), but use external combustion, they are expected to have the lowest emissions possible for a given electrical output. Their output is DC, and with appropriate series connection of modules, AMTEC can deliver voltages to match those provided by the battery systems of electric vehicles either for charging or for direct operation of electric motor drives. While AMTEC systems have been under development for years, recent advances made in programs directed toward spacecraft power systems have led to much simpler cell designs, far higher reliability, greatly improved modeling methods, and a clear path to modules appropriate for the assembly of multi-kilowatt systems. Phase I demonstrated an 18% efficient single-tube cell and the feasibility of producing, operating, and accurately modeling the experimental performance of multi-tube, series-connected AMTEC cells. In Phase II, a full scale system design will be developed and used to guide experiments whose results should allow a clear test of the feasibility of the AMTEC approach. A series of experimental cells will demonstrate the advanced component technologies required to reach 35% to 40% thermal efficiency, and the analytical models will then be used to determine the feasibility of a full scale system. Phase II will conclude with an assessment of AMTEC utility for vehicle applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: In Phase III, auxiliary power units for hybrid-electric vehicles will be assembled and tested in vehicles. They will be able to improve vehicle range and reduce emissions to well below expected standards. As stand-alone modules, the same AMTEC devices that can be assembled into large systems for vehicles can be utilized as residential generators in continuous gas furnaces, for remote power in recreational vehicles, for rural power generation from biomass fuels, and for cathodic protection of pipelines.

44

A Clean and Efficient Thermophotovoltaic Generator for Electric Vehicles--JX Crystals, Inc., 1105 12th Avenue Northwest, Suite A2, Issaquah, WA 98027-8994; (206) 392-5237
Dr. Lewis M. Fraas, Principal Investigator
Mrs. Jany Xiang Fraas, Business Official
DOE Grant No. DE-FG03-94ER81795
Amount: $749,997

Conventional internal combustion models are widely used in commercial and military sectors for remote, back-up, and portable power. Existing problems include low fuel efficiency, high maintenance, emissions, and noise. A thermophotovoltaic energy system to cogenerate electricity and heat can be used to address all of these problems. In Phase I, a thermophotovoltaic demonstration unit was developed which proved that electricity could be generated by surrounding an emitter radiating in the infrared with infrared-sensitive photovoltaic cells. Because the only moving part was a fan, the potential for low noise and low maintenance was demonstrated. A constant burn temperature allowed emissions to be much lower than those from a periodically exploding internal combustion engine. The potential for high efficiency was demonstrated by using the waste heat for space and water heating, and the cost and size estimates were shown to be in line with existing generators. Phase II will optimize components, develop a one kilowatt cogenerator, and install a thermophotovoltaic system in an existing electric car.

Anticipated Results/Potential Commercial Applications as described by the awardee: Remote location cogeneration of electricity and heat should be the earliest commercial application. Other early applications include remote generation for telecommunications and gas pipeline equipment, back-up generation for homes and businesses, and mobile generation. With economies-of-scale, it appears possible to create markets for on-grid cogeneration, and on-board generation for electric vehicles. In each case, thermophotovoltaic generation promises clean and efficient use of domestic fuels.

DESIGN AND APPLICATIONS OF NOVEL MATERIALS

45

Economical Photochromic Films Based on Metal Oxides--EIC Laboratories, Inc., 111 Downey Street, Norwood, MA 02062-2668; (617) 769-9450
Dr. R. David Rauh, Principal Investigator
Dr. A. C. Makrides, Business Official
DOE Grant No. DE-FG02-94ER81743
Amount: $736,720

The goal of this project is to develop a robust thin film coating, less than two microns thick, that can be applied to surfaces, rendering them photochromic in sunlight with respect to both the visible and near infrared components of the solar spectrum. Computer models have anticipated that photochromic windows would give rise to significant energy savings by solar management, particularly in buildings dominated by their cooling load. The planned coatings are derived from thin film transition metal oxides and are expected to be economical in materials and preparation, robust, and insensitive to environmental degradation. The objective of Phase I was to demonstrate a new highly active metal oxide film employing a novel means of sensitization. The photocoloration rate of tungsten oxide was increased 16-fold using this approach and the final optical density by a factor of three. The best Phase I films showed photocoloration under simulated solar conditions from 0.8 to 0.3 luminous transmittance with a coloration time of about 30 minutes, sufficient for energy control applications. However, bleaching times in air exceeded 24 hours, and the dynamic range degraded after a few cycles. The objective of Phase II is to further improve the technology to achieve films with similar dynamic coloration properties but with bleaching rates in the dark of about 30 minutes, and greater than one thousand cycles without loss of dynamic range. Phase II will focus on the reversibility of the sensitization process along with film fabrication methods applicable to the incorporation of a variety of possible sensitizer materials, extending approaches initiated in Phase I. Phase II will also develop a process for deposition onto polymer substrates used in window control films. Analyses of manufacturing costs and of solar energy transfer through windows incorporating photochromic films will also be carried out, permitting a final estimate of energy payback in various climates.

Anticipated Results/Potential Commercial Applications as described by the awardee: A thin photochromic film which can be applied to surfaces at a cost of <$2/square foot is anticipated. Commercially, such a film would have extensive markets in building windows and skylights, automotive windows, and sunroofs as well as eyewear. Aircraft cockpits would also benefit from photochromic coatings for thermal control and enhanced viewability of displays in bright sunlight.

46

A Novel High Strength Ceria-Zirconia Toughened Alumina Ceramic with Superior High Temperature Corrosion and Erosion Resistance--Selee Corporation, 700 Shepherd Street, Hendersonville, NC 28792-6472; (704) 697-2411
Dr. Giulio A. Rossi, Principal Investigator
Mr. Kenneth R. Butcher, Business Official
DOE Grant No. DE-FG05-94ER81859
Amount: $425,165

This project deals with the development of a novel ceramic material with superior strength and corrosion and erosion resistance in high temperature environments. This material was shown to exhibit strength and thermal shock resistance superior to that of alumina and mullite. Phase I showed it to have excellent resistance to high temperature sulfates and alkalies, though the tests were not of long enough duration to demonstrate this conclusively. In Phase II samples of open celled ceramic foam will be fabricated by impregnation of a polyurethane foam with an aqueous ceramic slurry followed by drying and firing to burn out organic material and densify the foam struts at high temperature. Several variables will be studied including the zirconia/alumina ratio, particle size and several processing variables. The samples will be physically characterized. High temperature cycling will also be done using a gas burner rig. Degradation of the modulus of elasticity as the result of thermal cycling will be carried out. Samples will also be exposed to high temperature and pressure in atmospheres typical of the integrated gasification combined cycle and pressurized fluid bed combustor coal burning processes. The exposed samples will be examined for evidence chemical attack.

Anticipated Results/Potential Commercial Applications as described by the awardee: A strong corrosion resistant product or family of products based on ceria-zirconia toughened alumina will be developed and tested. Their primary applications are intended for ceramic particulate filters or other components exposed to coal derived hot gases where they could replace existing aluminosilicates and non-oxide ceramics. In addition, this combination of properties should prove useful in other applications including catalyst supports for the hydrogen cyanide and nitric acid industries.

47

Design and Applications of Close-Spaced Thermionic Converters with Novel Isothermal Electrodes--Space Power, Inc., 621 River Oaks Parkway, San Jose, CA 95134-1907; (408) 434-9500
Mr. Gary O. Fitzpatrick, Principal Investigator
Mr. Joseph A. Dodson, Business Official
DOE Grant No. DE-FG03-94ER81864
Amount: $750,000

Thermionic converters with close-spaced interelectrode gaps are capable of substantial performance improvements over conventional ignited mode diodes. At very close gaps (2 to 10 microns), a thermionic converter operates in the collisionless Knudsen mode with nearly double the output voltage of conventional diodes and concomitant increases of efficiency. In Phase I a special electrode structure which can accommodate high heat flux without distortion was investigated. This type of electrode is needed in order to maintain an interelectrode gap of about five microns and to avoid short circuiting by thermal expansion deformation. In Phase I a laser interferometric technique was also developed to measure the thermal expansion deformation of electrodes with high heat fluxes passing through them. In Phase II the electrode investigation will be further extended with new features to increase power density and higher operating temperatures. The higher power density operation is attractive for utility topping cycles and cogeneration. Additional experiments using laser interferometry will be carried out in

Phase II, and complete thermionic converters with novel features to produce substantially increased efficiency and power density will be tested. Prototypic devices with silicon carbide hot shells will be constructed and operated in an effort to develop a practical diode for commercial applications. Although electrical heat sources will be used for experimentation in Phase II, the type of converters which will be built would be suitable for operation with flame heat sources or solar concentrators operating in atmospheric air.

Anticipated Results/Potential Commercial Applications as described by the awardee: An anticipated result is the demonstration of new milestones for thermionic converter performance in terms of efficiency and power density. Successful development of these devices will have commercial applications for remote power systems, cogeneration applications, topping cycles of central station power plants, hybrid electric vehicles, and solar thermal power systems for both space and terrestrial operation. Very large savings in fuel costs and reduction in air pollution could result from pervasive adoption of successful close-spaced thermionic converter applications.

48

Development of Metal Hydride Materials for High Coefficient of Performance Heat Pumps--
Thermal Electric Devices, Inc., 1704 Stanford Drive, SE, Albuquerque, NM 87106-3323; (505) 846-4822
Dr. K. Thomas Feldman, Jr, Principal Investigator
Dr. Charles Stein, Business Official
DOE Grant No. DE-FG05-94ER81890
Amount: $750,000

An efficient hydride reactor is necessary to allow an environmentally clean hydride heat pump to achieve its potential to be twice as efficient as current systems. A practical and cost effective method of coating hydride particles with high thermal conductivity copper and then compressing and sintering them into porous powder metal hydride (PMH) compacts with improved heat transfer was developed in Phase I. Thermal conductivity, k = 7.5 W/m°C was measured on green PMH compact pellets, a factor of 18 better than that of uncoated hydride particles. Transient analysis of reactor performance with a numerical code indicates only k = 5 W/m°C is required to achieve an adequate heat transfer rate for the heat pump. Further optimization of the PMH compacts is needed to improve thermal conductivity to 10 W/m°C which will provide excellent heat pump performance. Phase I results are highly promising. Phase II will further develop the PMH compacts into the shape of disks that can be press fit into a hydride reactor. The PMH compact disks will have grooves to improve hydrogen flow and will have thermal conductivity of at least 10 W/m°C. PMH compact disks with embedded high thermal conductivity fibers will be explored as composite structures with high thermal conductivity and strength. Hydride reactors with these PMH compact disks will be built and tested for thermal performance. The numerical analysis code for heat driven hydride reactors will be rewritten to describe the more promising compressor driven hydride heat pump. The performance of the hydride heat pump including electric energy consumption, cooling rate, coefficient of performance, weight, volume, cost, and life cycle cost will be predicted and compared both with the experimental test data and with performance data of conventional vapor compression systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: Optimized hydride reactors will allow the environmentally clean hydride heat pump to provide a nearly 50% reduction in the electric power required by refrigerator/freezers, air conditioners, and heat pumps, used in both domestic and commercial applications including vehicles. The new system will be smaller and have lower life cycle costs than conventional systems. The system is inherently clean and has no adverse environmental impact. These advantages provide a strong incentive to develop the hydride heat pump to its full potential.

MATERIALS SCIENCES INSTRUMENTATION

49

X-ray Absorption Spectroscopy for Trace Analysis of Chemical Phase and Composition--Advanced Fuel Research, Inc., 87 Church Street, P.O. Box 380379, East Hartford, CT 06138-0379; (203) 528-9806
Dr. David B. Fenner, Principal Investigator
Dr. David G. Hamblen, Business Official
DOE Grant No. DE-FG05-94ER81861
Amount: $749,809

X-ray absorption spectroscopy (XAS) based at synchrotron facilities is an established research tool in a variety of fields, including biochemistry, catalysis, and materials science. Commercialization will depend on increased performance of the x-ray detection system, generation of a suitable XAS spectral library, and development of a standard quantitative analysis methodology for determining the metal oxidation from the x-ray absorption near edge spectroscopy and detailed speciation from the extended x-ray absorption fine structure. In Phase I feasibility was demonstrated by constructing and testing an advanced detector system and by using that system to measure the x-ray absorption spectra of metal contaminated samples. There will be two major thrusts in Phase II: (1) hardware improvements to increase the sensitivity, energy resolution, and stability of the detector system, and (2) technique development, including the measurement of characteristic reference spectra, for determining speciation and valence of the detected trace elements. The goal of this project is a commercial service based upon the National Synchrotron Light Source at Brookhaven National Laboratory as well as other synchrotron x-ray sources. The information gained from this project will also contribute to evaluation of the potential for application of the technology to related areas of x-ray research.

Anticipated Results/Potential Commercial Applications as described by the awardee: Benefits include an increase in the cost effectiveness and standardization of the XAS technique, thereby enhancing the commercial potential for analytical services based on this technique for use in the growing fields of biochemistry, environmental control and remediation, and others. There is also a considerable market for an inexpensive, high-performance x-ray detector in the many government, academic, and industrial research institutions that already utilize XAS in their research activities.

50

An Apparatus for Structural Analysis of High Temperature Materials Using Synchrotron Radiation--Containerless Research, Inc., 910 University Place, Evanston, IL 60201-3149; (708) 467-2678
Dr. Shankar Krishnan, Principal Investigator
Dr. Paul C. Nordine, Business Official
DOE Grant No. DE-FG02-94ER81732
Amount: $750,000

This project concerns the development of apparatus and techniques for performing structural analysis of materials at high temperatures using synchrotron radiation. The Phase I results represent a breakthrough in methodologies for structural measurements at high temperature. The key technical innovation in this research is the use of containerless techniques to position solid and liquid specimens in the x-ray beam. This approach (1) eliminates specimen interaction with the container walls, (2) allows access to metastable states through undercooling and allows in-situ formation of glassy materials, (3) eliminates container contributions to diffraction and absorption spectra, and (4) allows control over specimen chemistry. The feasibility of x-ray measurements on liquids and solids at high temperature under containerless conditions was demonstrated in Phase I. X-ray diffraction measurements were obtained on levitated oxide melts including bismuth oxide, barium oxide-bismuth oxide, gallium oxide-bismuth oxide, and yttrium-boron-copper oxide (1-2-3) superconductors. Phase II will (1) develop a turn-key instrument capable of containerless, high-temperature structural measurements on highly reactive, high-melting liquid and solid materials, (2) provide x-ray diffraction studies on important high temperature materials of commercial and scientific interest, and (3) investigate different x-ray measurement techniques and x-ray data analysis and software development. Successful completion of Phase II will allow researchers to obtain in-situ structural information on molten materials at high temperatures for the first time. Application to a wide range of materials will be possible, including solid and liquid ceramics, battery materials such as halides, fluorides, and molten salts, metals and alloys (superalloys, transition metals), and semiconductor materials (silicon, germanium, indium arsenide) without any container interactions or contamination. Controlled in-situ synthesis of new nanophase, electronic, and amorphous materials will also be facilitated by the use of real-time structural measurements with synchrotron radiation.

Anticipated Results/Potential Commercial Applications as described by the awardee: Phase II will provide the capability for structural measurements on virtually any material and on liquids at temperatures up to at least 3000 K and will enable the controlled synthesis of new materials.

IMPROVED ONSTREAM METHODS OF NONDESTRUCTIVE EVALUATION

51

Application of the Meandering Winding Magnetometer to an In-Situ Determination of Age Related Degradation--Jentek Sensors, Inc., 1616 Soldiers Field Road, Boston, MA 02135-1181; (617) 254-5552
Dr. Neil J. Goldfine, Principal Investigator
Dr. Neil J. Goldfine, Business Official
DOE Grant No. DE-FG02-94ER81792
Amount: $750,000

Fatigue is of vital importance to energy production and distribution facilities. Fatigue failures are widespread and account for most mechanical failures, with estimates ranging from 50 to 90 percent. Fatigue failures are also frequently catastrophic and almost always without warning. Phase I evaluated the ability of the Meandering Winding Magnetometer (MWM) to detect fatigue damage nondestructively. The MWM represents a significant advance of eddy current testing technology. Conductivity measurements with a repeatability of 0.3 percent have been demonstrated in the laboratory using an MWM sensor on nonferromagnetic materials. This is a substantial improvement over the 1 to 2 percent repeatability achievable with conventional eddy current sensors. This sensitivity is made possible by the accuracy with which sensor response can be modeled. The model also provides compensation for variations in lift-off as small as a fraction of a micron. Leading nondestructive evaluation researchers believe that increased measurement sensitivity is critical to being able to take advantage of conductivity changes to determine material condition. Phase I supported this position. The MWM inspection systems was shown to be capable of detecting cumulative fatigue damage in stainless steel. The MWM measurement precision allowed quantification of fatigue usage to within 10% of fatigue life. The MWM system was also shown to be capable of identifying the area exposed to the highest stresses in a nonuniform stress field. Phase II will further validate the MWM system for detecting and quantifying cumulative fatigue damage by conducting demonstrations on (1) additional specimens subjected to uniform loading, (2) specimens subjected to variable amplitude, or irregular loading, (3) specimens subjected to nonuniform stress distributions, and (4) specimens of service-exposed combustion turbine blades.

Anticipated Results/Potential Commercial Applications as described by the awardee: A nondestructive method of determining cumulative fatigue damage, prior to the formation of detectable cracks, would be extremely valuable to owners and operators of energy production and distribution facilities, It would permit earlier identification of structures or parts of structures experiencing accelerated fatigue, provide a means of monitoring those areas to track progressive fatigue usage, and provide necessary information to support decisions to repair or replace the affected components.

ADVANCED GEOPHYSICAL IMAGING IN GEOSCIENCES RESEARCH

52

A Superconducting Magnetometer/Gradiometer for Advanced Geophysical Imaging--Conductus, Inc., 10623 Roselle Street, San Diego, CA 92121-1506; (619) 550-2700
Dr. Douglas N. Paulson, Principal Investigator
Dr. Duane B. Crum, Business Official
DOE Grant No. DE-FG03-94ER81730
Amount: $750,000

Borehole-to-borehole and surface-to-borehole measurements are of great interest for many geophysical applications since they can provide better information about the subsurface structure than a surface-to-surface measurement. Unfortunately, existing magnetometers are not adequate for many of these measurements. Although induction coils are available, it is difficult to get good sensitivity to horizontal fields. The required coils are expensive and/or too large. During Phase I a 3-axis magnetometer system based on this technology was built and tested on the earth's surface. These tests demonstrated the feasibility of building these sensors into a borehole tool having the needed sensitivity. Phase II will develop an entirely new geophysical magnetometer sensor for this application based on high-temperature superconducting technology. The sensor will be integrated into a new tool, comprising everything required for operation in boreholes up to a depth of 500 meters. It will be capable of measuring all three magnetic field components plus five independent magnetic gradients

Anticipated Results/Potential Commercial Applicationsas described by the awardee: This new sensor, along with its associated analysis software, should provide significant benefits in a number of surface and borehole applications, including environmental remediation, enhanced oil recovery, unexploded ordnance detection, mine detection ground water contamination, and petroleum leakage.

CHEMICAL SCIENCES RESEARCH

53

An Advanced Electrochemical Sensor for the Simultaneous Analytical Measurement of Three Chemical Species---Andcare, Inc., 2810 Meridian Parkway, Suite 152, Durham, NC 27713-2277; (919) 544-8220
Dr. Marek Wojciechowski, Principal Investigator
Mr. John P. O'Daly, Business Official
DOE Grant No. DE-FG05-94ER81706
Amount: $750,000

The requirements of complex sample monitoring present a growing need for a new generation of sensors with small size and multi-analyte capability. This project will determine whether screen printing of basic sensor components and circuitry, followed by precision deposition of colloidal gold enzyme conjugates and other analytical reagents onto the surface of working electrodes, can yield high performance, disposable sensors. Phase I showed the feasibility of using electrochemical sensors and monitors for the determination of multiple chemical species. This makes possible the development of new instrumentation needed for process monitoring, environmental testing, and medical diagnostics. In Phase II, the sensor/monitor will be developed and manufacturing prototypes will be produced. Principles of multi-analyte sensor design, operation, and manufacture will be developed to set the stage for the broadest possible range of operating capabilities. Phase II will also develop the first in a line of commercial products with sensors for simultaneous measurement of total cholesterol, high density lipoproteins (HDL), and triglycerides. The inexpensive manufacture of printed sensor electrodes allows for use of factory calibrated disposable sensors whose output is coupled to an inexpensive, hand-held monitor. This approach eliminates the time consuming care of reusable sensors.

Anticipated Results/Potential Commercial Applications as described by the awardee: Potential applications of the electrode design resulting from this research are advanced biosensors for monitoring multiple analytes in a complex sample. Commercial applications include an advanced electrochemical sensor able to simultaneously measure total cholesterol, HDL, and triglycerides, and a sensor able to measure a combination heavy metals.

54

Highly Selective Membranes for the Separation of Organic Vapors Using Superglassy Polymers--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025-1516; (415) 328-2228
Dr. Ingo Pinnau, Principal Investigator
Ms. E. G. Weiss, Business Official
DOE Grant No. DE-FG03-94ER81811
Amount: $750,000

The separation of organic vapors from permanent gases is a process of considerable industrial importance. Applications include the separation of organic vapors from industrial effluent air streams, of hydrocarbons from refinery hydrogen purge streams, and of higher hydrocarbons from methane in natural gas processing. Membranes that are preferentially permeable to the minor organic component are being developed for these applications. For an efficient process, a high organic vapor/permanent gas selectivity and a high vapor flux are required. Rubbery polymers, which are organic vapor selective, are in limited commercial use, but have inadequate selectivity for many applications. In Phase I the use of PTMSP [poly(1-trimethylsilyl-1-propyne)], a high-free-volume, superglassy polymer, was investigated as an advanced vapor separation membrane material. PTMSP membranes are extraordinarily effective at separating organic vapors from permanent gases. Membrane selectivities are two to ten times higher. Furthermore, good long-term stability of PTMSP in an organic vapor environment was demonstrated. In Phase II optimized PTMSP composite membranes will be developed and the best membrane formed into industrial-size modules for pilot-testing. The long-term performance and stability of PTMSP composite membranes will be tested in a pilot system with hydrocarbon/hydrocarbon and hydrocarbon/methane mixtures.

Anticipated Results/Potential Commercial Applications as described by the awardee: Membranes made from high-free volume, superglassy polymers could have significant impact on many important industrial vapor separation applications. Possible applications include the recovery of hydrocarbons from natural gas and the removal of hydrocarbons from hydrogen in the refinery and petrochemical industries. The superior selectivity and permeability of superglassy polymers compared to state-of-the-art rubbery or glassy membranes make these membrane systems competitive with conventional separation methods such as cryogenic condensation.

ATMOSPHERIC MEASUREMENT AND SAMPLING TECHNOLOGIES

55

An Agile, Tunable Mid-Infrared Source (7-14 microns) Utilizing Room Temperature Near Infrared Diode Lasers for Measuring Atmospheric Trace Species--Aerodyne Research, Inc., 45 Manning Road, Billerica, MA 01821-3976; (508) 663-9500
Dr. Roger S. Putnam, Principal Investigator
Dr. Charles E. Kolb, Business Official
DOE Grant No. DE-FG02-94ER81698
Amount: $749,897

Tunable infrared laser differential absorption spectroscopy (TILDAS) has proven to be a powerful technique for accurately determining concentration and fluxes of trace pollutants. While some TILDAS systems utilize tunable diode lasers (TDLs) in the near-infrared region (0.7 to 2.0 μm), most systems use cryogenic lead salt TDLs in the mid-infrared (three to 20 μm) since molecular detection is typically 20-200 times more sensitive in this wavelength region. However, cryogenic mid-infrared TDLs have a number of operational drawbacks: the requirement for cryogenic cooling, narrow tuning ranges between mode hops, and narrow single diode frequency coverage. This project will demonstrate an agile, widely tunable difference frequency mid-infrared source which will overcome the major operating problems associated with current, cryogenic mid-infrared diode sources. This advance will greatly expand the range of trace species pollutant measurement problems which can routinely be solved with TILDAS technology. Phase I demonstrated mid-infrared radiation at 11.5 microns by nonlinear difference frequency generation in a gallium selenide crystal using room temperature diode lasers at 807 and 868 nm. Smooth tuning in resolving a set of five closely spaced ammonia absorption lines by current tuning the diode lasers was also demonstrated. Phase II will demonstrate an infrared source capable of tuning from 7 to 14 microns in an optical trace gas detection system. The system will be self aligning and can be programmed to measure different trace gases at widely separate wavelengths without any operator intervention.

Anticipated Results/Potential Commercial Applications as described by the awardee: The room temperature, tunable mid-infrared source planned here will directly replace cryogenic tunable diode lasers currently used in environmental and industrial monitoring of trace species concentrations. The resulting trace species monitors will be non-cryogenic, simpler to operate, and capable of sensitive detection of a much larger number of pollutants.

BACTERIAL IDENTIFICATION AND SAMPLING

56

Development and Application of Gene Probes to Determine Degradation Potential and to Improve In-Situ Bioremediation Efforts--Envirogen, Inc., 4100 Quakerbridge Road, Lawrenceville, NJ 08648-4702; (609) 936-9300
Dr. Robert J. Steffan, Principal Investigator
Mr. William J. Guarini, Business Official
DOE Grant No. DE-FG05-94ER81759
Amount: $683,583

The goal of this project is the development of a commercial analytical tool that will employ gene probes to select the most economical remediation alternative for polluted sites. Probes are to be developed to allow the determination of the natural bioremediation potential of contaminated aquifers and soils. Additional probes will be developed for use in monitoring the performance of commercial bioreactors. The product of the work should be sets of immobilized gene probes (both catabolic and strain-specific) that can be cost-effectively used to analyze samples from polluted sites or bioreactors to determine the feasibility of various remediation alternatives and to optimize the performance of a chosen technology. During Phase I methods were developed for generating DNA fingerprints of indigenous and selected degradative microorganisms. The fingerprints were used to select strain-specific gene probes. Phase II will involve using the gene probes to predict the feasibility of natural attenuation as a pollution remediation alternative, to monitor and optimize the effect of biostimulation (bio-sparging) for remediating a gasoline-contaminated aquifer, monitor organisms added to remediate trichloroethylene-polluted groundwater, monitor the performance of a commercial-scale bioreactor. A semi-automated method for selecting gene probes and collecting genetic information (DNA fingerprints) about degradative microorganisms will also be developed. The method will use computerized image analysis technology to collect and store DNA fingerprint information, and analyze the DNA fingerprints to select DNA fragments that are suitable for use as gene probes. Molecular probes will allow an assessment of mixed populations of degradative microorganisms and improve the understanding of degradative processes. Cost savings over traditional remediation approaches will be realized by allowing rational selection of most appropriate treatment technologies on a site-specific basis and an optimization of remediation activities.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project should result in the development of sets of gene probes that can be efficiently used to predict the potential use of natural remediation processes for polluted sites thereby reducing the cost of remediation compared to traditional technologies. The probes will also allow optimization of ex-situ biological treatment processes and the performance of bioreactors.

HEALTH EFFECTS

57

Signal Amplification for Specific Nucleic Acid Detection--Third Wave Technologies, Inc., 2800 South Fish Hatchery Road, Madison, WI 53711-5399; (608) 273-8933
Ms. Mary Ann D. Brow, Principal Investigator
Dr. Lance Fors, Business Official
DOE Grant No. DE-FG02-94ER81891
Amount: $750,000

Deoxyribonucleic acid (DNA) sequence analysis has become one of the most important tools in modern biology. Unfortunately, it has yet to penetrate clinical medicine because of the lack of rapid, robust, inexpensive, and highly reproducible methods for detecting DNA and ribonucleic acid (RNA) sequences and sequence changes associated with human diseases. The need for such a method is acute and is a critical component in shifting U.S. health care emphasis from very expensive post-symptomatic treatments to more cost-effective disease prediction and prevention. This project will fill that need by developing and commercializing a novel, high-speed and automatable DNA and RNA diagnostic technology for the specific detection of nucleic acid sequences associated with human disease. This technology is based on the discovery that a structure-specific nuclease of several thermostable DNA polymerases can be engineered to direct the cleavage of DNA and RNA at one and only one location. This allows the development of a very fast, sensitive, specific, robust, and isothermal cleavage-based DNA diagnostic product platform. In Phase I, the signal released from the recognition of the target sequence propagated through a signal amplifying cleavage cascade was successfully achieved. In Phase II, the development of this innovative and broadly enabling nucleic acid detection technology will be completed that can play a significant role in making cost-effective, large-scale early detection, diagnosis, and monitoring of a wide variety of diseases a reality.

Anticipated Results/Potential Commercial Applications as described by the awardee: The signal amplification technology for the detection of DNA and RNA sequences and sequence changes should significantly increase the speed and decrease the cost of detecting, diagnosing, and monitoring a wide variety of diseases and disorders. The technology is expected to be fast, simple, specific, sensitive, robust, reproducible, and user-friendly.

HUMAN GENOME

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Low Cost Automated Preparation of Plasmid, Cosmid, and Yeast DNA--MacConnell Research Corporation, 11339 Sorrento Valley Road, San Diego, CA 92121-1303; (619) 452-2603
Dr. William P. MacConnell, Principal Investigator
Dr. William P. MacConnell, Business Official
DOE Grant No. DE-FG03-94ER81802
Amount: $750,000

This project is developing and site testing a cost effective, high through-put automated instrument that purifies plasmid, cosmid or genomic DNA in sufficient yield and purity to allow its direct use in molecular biology research protocols including automated fluorescent DNA sequencing. The instrument uses proven electrophoretic separation technology to simultaneously isolate DNA from multiple samples of bacterial culture or other lysed cells. The electrophoretic separation method employs a disposable 96 channel gel cassette/electroelution device to both separate and recover DNA from crude starting samples in a process that has only two moving parts associated with its separation process. Phase I proved the feasibility of the 96-channel separation process and the instrument concept. It showed that 3-5 micrograms of high purity plasmid DNA or 1-2 micrograms of cosmid or genomic DNA could be isolated from bacterial culture or lysed cell sources, respectively, with a prototype 96-channel cassette and manually operated electrophore is processing rig. Purified DNA samples obtained from the Phase I prototypes were shown to be pure enough and in sufficient yield for automated fluorescent DNA sequencing as well as several other molecular biology protocols. All steps of the prototype separation device could be easily automated by the processing instrument to be developed in Phase II. Phase II will (1) optimize both run parameters and chemistry, (2) develop a reproducible, robust processing instrument and cassette rig, (3) contract for injection molding of the 96-channel disposable cassette, (4) thoroughly test the instrument and final cassette design using multiple types of vectors and E. coli strains, and (5) site test the instrument.

Anticipated Results/Potential Commercial Applications as described by the awardee: The instrument to be developed is directly applicable and cost-effective for laboratories carrying out Human Genome research. The instrument will also be useful to molecular biology labs in general. Automated, cost effective, small-scale preparation of DNA is of central importance to molecular biology researchers.

PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

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A Continuous Cryopump/Pellet-Fabrication Apparatus for Fusion--Cryogenic Applications F, Inc., 450 Bacon Springs Lane, Clinton, TN 37716-5311; (615) 435-5433
Dr. Christopher A. Foster, Principal Investigator
Dr. Christopher A. Foster, Business Official
DOE Grant No. DE-FG05-94ER81734
Amount: $748,826

Fusion reactors based on the magnetic confinement of plasmas will require active fueling to replenish the deuterium-tritium escaping the plasma. Cryogenic pumps and frozen pellet injection are the most efficient means of pumping and refueling the tokamak plasma. Since the burn rate of the reactor is only a few percent, the exhaust gas will have large quantities of unreacted deuterium and tritium. Since tritium is a radioactive gas, it is important to limit the total tritium inventory of the reactor to a minimum. This will require rapid recycling of the tritium pumped from the reactor into the pellet fuel injection system and back into the plasma. The planned effort will accomplish this with a continuous cryogenic pumping system which will receive the exhaust from the plasma and produce high quality frozen deuterium-tritium pellets suitable for directly feeding a centrifuge pellet injector. The cryopump will thus be able to greatly reduce the tritium inventory by recycling the fuel back into the plasma within a few minutes from the time the fuel enters the pump. In addition, the planned pump/pellet fabrication system, which consists of an array of cryopanels, will be capable of continuous pumping and fueling with no moving parts, including valves. The inherent simplicity of the system will thereby greatly increase the reliability and reduce the cost of the apparatus as compared to conventional pumping and pellet fueling systems. During Phase I a small proof-of-principle pump was constructed which demonstrated the capability of the apparatus to both cryopump deuterium and produce high-quality deuterium pellets with no moving parts. A conceptual design of a full scale International Thermonuclear Experimental Reactor pumping and fueling system has been completed. The design contains no moving parts and has a total tritium inventory of 40 grams. During Phase II full-scale prototype primary and secondary pellet/pumps will be constructed and tested with deuterium and helium.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will lead to a practical continuous cryogenic pumping system which will produce frozen pellets of deuterium-tritium as the exhaust. Such an apparatus will greatly simplify a fusion reactor fuel cycle and dramatically reduce the tritium inventory, and therefore, the passive safety of future commercial fusion reactors. The simplicity of the pump, which contains no moving parts, makes it attractive for development into a commercial vacuum pump for semiconductor processing.

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Economical and Reliable Niobium-Tin Conductors via Innovations in Stabilizers--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06704-1039; (203) 753-5215
Dr. Hem C. Kanithi, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81782
Amount: $750,000

Copper stabilizer used in niobium tin (Nb_3Sn) superconductors is a critical component both in terms of product performance and cost. The present method of making the stabilizer member by tubular hot extrusion is expensive. Limited ductility of the refractory diffusion barriers which are part of the stabilizers have caused undesirable wire breaks or restricted the production lot size to a small weight. This project will develop reliable and significantly more economical Nb_3Sn conductors by improving the stabilizers. In Phase I the feasibility of producing them by a hot isostatic pressing (HIP) approach was established. HIP conditions necessary for a good bond between the various components were determined. Barrier materials (Nb, tantalum, and a combination of the two) were incorporated in sub-scale stabilizers which were evaluated by co-drawing with composite materials. Long lengths of wire with uniform diffusion barriers were fabricated. Following the success of Phase I, scaled-up designs, necessary non-destructive, on-line inspection, and cost details for large quantity production will be addressed in Phase II. Mechanical and material designs for the more successful stabilizer configurations of Phase I will be further improved, particularly for larger lot sizes than conventional ones. The planned development will explore novel techniques to achieve low alternating current (AC) losses by maintaining uniform filament geometry in the internal-tin conductors suitable for the International Thermonuclear Experimental Reactor (ITER) program. In addition to the widely used Nb - 7.5%Ta for the filaments, Nb - 1.3%Ti will be investigated. The achievement of high current density and low AC losses, concurrently and individually, will be the focus of this project, thus addressing the needs of ITER and commercial markets.

Anticipated Results/Potential Commercial Applications as described by the awardee: The primary result of this project will be the development of an economical, high-rate production process for Nb_3Sn conductors. By design innovation and process simplification, their reliability for any device application will be increased. It is expected that a third of the present internal-tin costs can be eliminated. Applications that will benefit from this research include magnets for fusion (ITER and the Tokamak Physics Experiment), superconducting motors and generators, future particle accelerator magnets, high-frequency nuclear magnetic resonance spectroscopy magnets, and high-field general purpose magnets.

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Improvement in the Loss and Critical Current Density Properties of Internal-Tin Niobium-Tin--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06074-1039; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81783
Amount: $750,000

The aim of this work is to further improve the properties of internal-tin niobium-tin (Nb_3Sn) strands for fusion applications. Using the internal-tin process, the losses in The Tokamak Physics Experiment (TPX) and the International Thermonuclear Experimental Reactor (ITER) type conductors were reduced by making a subelement consisting of three rings of slightly larger diameter filaments instead of the four usually employed. Even though the filament diameter was increased, so was the spacing between the filaments and this reduced bridging, producing a strand with lower losses. However, the losses are still too large to meet the ITER HP-2 specification. During Phase I, various ways of improving the critical current density (J_c) properties of the standard ITER HP-1 strand were explored. Phase I and other work on ITER and TPX conductors have shown that there are four areas that need to be addressed: (1) standardization of testing procedures and careful qualification of all organizations involved in testing, (2) apparent variability in properties of production lengths, (3) improved J_c with, at the most, a very small increase in losses in order to meet the HP-1 ITER specification with a sufficient margin to accommodate the property variability experienced in commercial production, and (4) lower losses with, at the most, only a small J_c decrease in order to meet the HP-2 ITER specification. Items 1 and 2 apply to both 3 and 4, and they are constantly being addressed in collaboration with base program groups and particularly the National Institute of Standards and Technology. This Phase II project will be devoted to making conductors to meet the HP-1 and HP-2 ITER specifications. The results of this work will also be applied to the improvement of Nb_3Sn for high field magnets for commercial applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: The work is primarily aimed at the development of a more reliable and economical high field material for ITER and TPX. The knowledge gained, however, will be used to improve internal-tin Nb_3Sn for other applications.

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Carbon-Carbon to Copper Joining for Fusion Reactor Applications--Surmet Corporation, 33 B Street, Burlington, MA 01803-3406; (617) 272-3250
Dr. Suri A. Sastri, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-94ER81877
Amount: $750,000

There is a critical need in DOE's magnetic fusion energy program for suitable technology to join plasma facing components such as carbon-carbon (C/C) composites to metals, notably copper (Cu). Because of the vast differences in the coefficients of thermal expansion, successful braze joining of C/C to copper is particularly challenging. Thermomechanical considerations of residual stresses would dictate the desirability of a low braze temperature. Commercially available active braze alloys (ABA), except Cu-ABA, cannot be used because of restrictions imposed by the neutron flux in the reactor. Cu-ABA has a high melting temperature close to the melting temperature of copper itself and does not provide enough operating latitude normally required for production use on a large number of parts to be brazed. Very stringent process and quality control measures and costly nondestructive evaluation methods will be needed to assure reliability if no acceptable alternatives to Cu-ABA can be developed. In Phase I, the technical feasibility of several innovative low activation, low temperature braze joining options was successfully demonstrated. The most significant is the discovery of a novel silver-free low activation ABA system that can melt congruently below 890°C. Phase II will focus on the further optimization of this alloy and the development of a convenient foil material. A thorough thermophysical and thermomechanical evaluation of joints between C/C and high strength copper fabricated with the use of these novel active brazes will be carried out in Phase II. These alloys have the potential to be effective in the joining of advanced ceramics to themselves or to metals, an area of application that is increasingly important both technically and commercially.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of microscopically homogeneous braze alloys of any required composition has broad generic implications. Advances in the microelectronics, automotive, and aircraft engine industries place a continually escalating need for braze alloys that are more reliable, have higher use temperature, and are environmentally friendly. These factors contribute to produce a strong commercial market demand for developing a more powerful and generic processing technology capable of significant control over preparation of braze alloy compositions that can meet the demanding needs of the future.

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Ductile Joining of Plasma Facing Components to Copper--Surmet Corporation, 33 B Street, Burlington, MA 01803-3406; (617) 272-3250
Dr. Suri A. Sastri, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-94ER81875
Amount: $750,000

Beryllium is an attractive plasma facing component for the International Thermonuclear Experimental Reactor (ITER), and a critical need exists for it to be bonded to copper. Braze joining has emerged as the most desirable bonding technique. However, beryllium and copper react with each other during brazing to form brittle intermetallic compounds that weaken the joint. The fusion reactor environment rules out the use of braze materials commonly used with beryllium. The key innovation of the Phase I proposal was the incorporation of a proprietary diffusion barrier coating on the beryllium surface that prevented the formation of brittle intermetallic phases in the joint. Results from Phase I soundly confirmed the validity of the diffusion barrier film approach. Reproducible beryllium-to-copper braze joints with excellent thermo-mechanical properties were fabricated. Joining was made possible by two developments: (1) a novel joining technique termed the braze diffusion joining process and (2) the development of an innovative braze foil design. This novel process, in conjunction with the diffusion barrier film, successfully joined beryllium to copper. Such joints are able to withstand large thermo-mechanical stresses. This process also helps join copper to copper, including the dispersion strengthened grades. The brazing is carried out at below 700°C but the joint can be heated to 900°C without joint failure. A methodical and detailed evaluation of the many ITER relevant joint properties such as thermal conductivity, mechanical strength, and the effects of neutron and hydrogen ion bombardment on these properties will be conducted in Phase II. The ability to withstand thermal shock and thermal fatigue will be tested and relevant nondestructive evaluation techniques identified. Process optimization and scale up will also be pursued during Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of microscopically homogeneous braze alloys of any required composition has broad generic implications. Advances in the microelectronics, automotive, and aircraft engine industries place a continually escalating need for braze alloys that are more reliable, have higher use temperature, and are environmentally friendly. These factors contribute to produce a strong commercial market demand for a more powerful and generic processing technology capable of significant control over preparation of braze alloy compositions that can meet the demanding needs of the future.

FUSION ENERGY SYSTEMS

64

A Multilayer Silicon Carbide (SiC) Fiber Coating for Toughened, Neutron Radiation-Resistant SiC/SiC Composites--Hyper-Therm High-Temperature Composites, Inc., 18411 Gothard Street, Units B and C, Huntington Beach, CA 92648-1235; (714) 375-4085
Dr. Robert J. Shinavski, Principal Investigator
Mr. Wayne S. Steffier, Business Official
DOE Grant No. DE-FG03-94ER81778
Amount: $422,016

Silicon carbide (SiC) has been identified as a promising material for fusion energy applications because of its low activation, low decay heat, and outstanding high-temperature mechanical properties. Continuous SiC fiber-reinforced SiC-matrix composites (SiC/SiC) are of particular interest because of their relatively high strength and toughness compared to that of monolithic SiC. Currently available fiber coatings such as carbon and boron nitride have demonstrated the desired mechanical characteristics necessary to promote high composite strength and toughness; however, the utility of these materials is severely limited by their susceptibility to mechanical degradation when exposed to neutron irradiation. This limitation is caused by the dimensional and microstructural instability of carbon and boron nitride fiber coatings as a result of radiation exposure. In Phase I, five densified SiC/SiC composite plates toughened by unbonded, uniform thickness SiC layers in their fiber coating systems were produced and evaluated to determine their corresponding tensile strength and fracture toughness characteristics. Comparison of the mechanical test results was made with that of a baseline state-of-the-art SiC/SiC composite system employing an optimized pyrolytic carbon (PyC) fiber coating. Results indicated that the engineered multilayer SiC fiber coating system emulates the desirable mechanical attributes of PyC necessary to impart high composite strength and toughness, and may possess the desired properties for increased neutron radiation and high-temperature oxidation resistance. Phase II will further investigate the feasibility and understanding of optimizing the multilayer SiC fiber coating system so as to maximize the strength and toughness of SiC/SiC composites for potential fusion energy and/or high-temperature structural applications. Optimization will consist of evaluating the combined effect of SiC layer thickness and number of unbonded SiC layers in the multilayer fiber coating system. Samples will be produced and evaluated to determine their corresponding monotonic tensile strength, cyclic fatigue, fracture toughness, and interfacial shear characteristics. Additional characterization will be carried out, and a semi-empirical predictive micromechanics model will be developed. Parametric analysis will be performed to determine the optimum multilayer fiber coating system design from which a final optimized composite system will be produced, evaluated, and correlated with the model. Additional samples from each composite variant will be used to determine their durability/survivability characteristics in a neutron radiation environment.

Anticipated Results/Potential Commercial Applications as described by the awardee: SiC-matrix composites are an enabling class of materials for first wall plasma containment, liner and divertor components in fusion energy systems, stationary turbine and power generation components, radiant burner and heat exchanger tubes, and for a variety of thermostructural applications in aerospace propulsion combustors and nozzles, hypersonic airframe thermal protection systems, and spacecraft re-entry heatshields.

PLASMA DIAGNOSTICS

65

A Spatial Detector Array for Measuring the Turbulence Distribution (S(κ,ω)) with the Heavy Ion Beam Probe--InterScience, Inc., 105 Jordan Road, Troy, NY 12180-8343; (518) 283-7500
Dr. Jeffrey Beackstead, Principal Investigator
Dr. James T. Woo, Business Official
DOE Grant No. DE-FG02-94ER81788
Amount: $528,166

The Heavy Ion Beam Probe (HIBP) has become a valuable diagnostic for measuring the plasma space potential, electron density, and more recently, the plasma current profile in Tokamak fusion experiments. However, because of the limitations placed on the design of the HIBP by the size and complexity of the electrostatic energy analyzer, only limited information can be extracted from HIBP's fluctuation measurements. By extending the range and number of sample volumes simultaneously recorded by the beam probe, a better understanding of the turbulence distribution, S(κ,ω), can be achieved. This can be accomplished by installing an array of secondary particle detectors close to the plasma edge. In Phase I, a particle detector was developed capable of measuring the small signal levels required by the HIBP in the high background environment associated with operating near the plasma edge. In addition, this detector was incorporated into the design of a 160-element, spatial array for the two MeV HIBP on the Texas Experimental Tokamak (TEXT). This array will substantially increase the range the HIBP can simultaneously measure. A flexible design was developed such that the array can make measurements that are nearly poloidally or radially aligned. As such, the array can be used to make direct comparisons between experimental measurements of S(κ,ω) and fluctuation theories such as drift waves, as well as investigate transient phenomena such as sawteeth and the low confinement to high confinement transition. These types of measurements can greatly enhance the understanding of the transport processes occurring in magnetically confined plasmas bringing the fusion community one step closer to producing a commercially attractive fusion reactor. The construction and implementation of the array on the TEXT will be carried out as part of Phase II. A detailed design was completed during Phase I such that the detector array can be fabricated and installed on TEXT within ten months of the start of Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of a spatial array of detectors will substantially increase the range the HIBP can simultaneously measure to address many of the physics issues related to plasma transport in much more detail than previously possible. The detector can also be incorporated into a wide variety of particle diagnostics for fusion plasmas. A better understanding of the physics governing the transport processes in magnetically confined plasmas will bring fusion research one step closer to producing a commercially attractive reactor.

NUCLEAR AND HIGH ENERGY PHYSICS EDUCATIONAL DEVICES

66

A Unique Educational Game with Interactive Tutorials for Learning about Accelerators, Detectors, and Particle Physics (The Multimedia Accelerator Game)--G. H. Gillespie Associates, Inc., P.O. Box 2961, Del Mar, CA 92014-5961; (619) 677-0076
Dr. George H. Gillespie, Principal Investigator
Dr. George H. Gillespie, Business Official
DOE Grant No. DE-FG03-94ER81768
Amount: $590,083

An innovative multimedia game concept has been developed to introduce precollege students to the world of particle accelerators, particle detectors, and elementary particle physics. The concept is a fast-moving accelerator simulation game which transports the student-player into the sub-atomic world of nuclear and particle physics. In Phase I, a prototype of this game was developed and preliminary evaluations of the game's educational benefits were conducted in collaboration with a high school. In Phase II, the game will be expanded with a multimedia introduction to an accelerator facility which places the student-player in the role of scientist. From an accelerator operations room, the player will be guided in the setup of an accelerator simulation experiment. The game will then illustrate the motion of charged particles in electric and magnetic fields, simple harmonic oscillations, repulsive forces between particles with the same charge, and other fundamental physics concepts. At different stages of the game, obstacles will be introduced which the player must overcome if the beam is to be successfully accelerated with adequate intensity to produce the collision event rate needed to reveal "new" elementary particles. The game ends with the student's beam producing collision events which are observed by detector technology. The simulation results are interactively analyzed by the player, with the aid of multimedia presentations in the form of videos and tutorials that provide an engaging learning experience.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project provides an innovative and unique new approach to support secondary physics and science education. Precollege students will have an exciting tool with which to learn about the world of accelerators, detectors, and nuclear and particle physics in a self-paced, interactive and entertaining environment. The multimedia accelerator game disk will run on popular personal computers, and will be affordable and accessible to any secondary school.

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The Particle Beam Optics Interactive Computer Laboratory (PBO Lab)--G. H. Gillespie Associates, Inc., P.O. Box 2961, Del Mar, CA 92014-5961; (619) 677-0076
Dr. George H. Gillespie, Principal Investigator
Dr. George H. Gillespie, Business Official
DOE Grant No. DE-FG03-94ER81767
Amount: $556,010

The particle beam optics interactive laboratory (PBO Lab) is an educational software tool to aid students in learning about charged particle beams and charged particle optical systems. The concept for the PBO Lab includes four key elements: (1) a graphical user interface shell that provides for a highly interactive learning session, (2) a knowledge database containing information on electric and magnetic optics transport elements, which provides interactive tutorials on the fundamental physics of charged particle optics and on the technology used in particle optics hardware, (3) a graphical construction kit that provides tools for students to interactively and visually construct optical beamlines, and (4) a set of charged particle optics computational engines that computes trajectories, transports beam envelopes, and carries out similar calculations for the student designed beamlines. A demonstration prototype of the PBO Lab was written during Phase I to demonstrate the integration of the TRANSPORT program as the primary computational engine. In Phase II, the PBO Lab will provide a new education aid for teaching particle beam optics, as well as a complete graphic user interface for the TRANSPORT and TURTLE programs, that will run on a variety of computer platforms.

Anticipated Results/Potential Commercial Applications as described by the awardee: The PBO Lab will provide with a new software aid for students learning about charged particle optics and accelerator principles, improve the scientific productivity of researchers, in laboratories and industry, involved in the design and development of accelerator technology and equip scientists and engineers with new capabilities for efficiently modeling and analyzing charged particle beamlines and accelerators systems.

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A Multimedia Software Tutorial on Superconducting Accelerator Magnets--MJB Consulting, 1415 Country Ridge Drive, DeSoto, TX 75115-7423; (214) 709-1957
Dr. Millicent Ball, Principal Investigator
Dr. Millicent Ball, Business Official
DOE Grant No. DE-FG05-94ER81813
Amount: $749,736

The objective of this project is develop a multimedia hypertext tutorial introduction to the basic concepts of physics and engineering used in developing of superconducting magnets for high energy physics accelerators. The target level for the tutorial is junior or senior level undergraduates, but by focusing on challenging technical research in the design of superconducting magnets for accelerators, it will also be of value to research institutes, industrial concerns, working scientists and others with an interest in applied superconductivity. The course material has been divided into 5 major sections: 1. Accelerators and Superconducting Magnets. 2. Characteristics of Superconductor for Accelerator Magnets. 3. Magnetic Design and Field Quality Considerations. 4. Integrating the Magnetic Design into the Final Magnet Configuration. 5. Magnet Quenching and Performance Measurements. The presentation of the material will make full use of the latest technology for hypertext, interactive, multimedia presentations, including video footage, sound, graphics, and animation. The presentations will be available on CD-ROM for PCs and MACs. An over-view subset, with most of the visual material, but not the tutorial lessons, will be made available via World Wide Web pages on the Internet global computer network as a public information resource. In Phase I, the subject material was collected and organized into the proposed course structure, and appropriate course authoring software was selected. In Phase II, the multimedia course will be produced. The individual sections will be tested by local college students, and then the complete course will be assembled and tested.

*Anticipated Results/Potential Commercial Applications*as described by the awardee: This project will provide a comprehensive college level course/tutorial on the design, construction and performance of superconducting accelerator magnets. This technology will also be applied to magnets for MHD propulsion and other superconducting magnet applications. The information will be marketed through educational catalogs, advertizing in technical journals, sent direct mail to research institutes, and available for industrial concerns and interested scientists and engineers.

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Innovative Software for Nuclear Physics Education--Scientific Digital Visions, Inc., 954 Emory Street, San Jose, CA 95126-1853; (408) 289-8494
Ms. Jennifer A. Blanc, Principal Investigator
Dr. Craig A. Stone, Business Official
DOE Grant No. DE-FG03-94ER81858
Amount: $750,000

The topics that are covered in nuclear physics courses are intriguing, but are often difficult to explore. Relational properties of nuclei, theoretical models, and laboratory experiments are cumbersome to apply and are not easily grasped in a classroom setting. Textbooks can only provide a static, limited view of nuclear physics. Students are therefore limited because they cannot explore the theories and facilities that are used in a nuclear physics career. Educational software for nuclear physics can effectively introduce students to the concepts of nuclear physics, can allow the students to explore the concepts and topics more thoroughly than in a classroom, and can promote student interest in the field of nuclear physics. In Phase I, the feasibility of presenting key nuclear physics concepts in an interactive multimedia environment was demonstrated. Text, sound, animation, video, still graphics, and user interaction in computer-based tutorials that demonstrate the feasibility of the project were effectively combined. Several electronic laboratories and demonstrations that give students hands-on interactive experiences with principles of nuclear physics were developed. An electronic encyclopedia was also designed which will allow the user to navigate easily through the various nuclear physics concepts. Phase II will expand on the Phase I research and develop the educational software into a commercial package. Through the framework of the nuclear physics encyclopedia, a student will be able to select a topic of interest. This topic will comprise several components, including multimedia-based tutorials, electronic laboratories, and electronic demonstrations. Special features will allow students and instructors to define the path through the topic, find specific references, and look up unfamiliar terms. The nuclear physics encyclopedia will provide classroom instructional tools, electronic nuclear physics laboratories, and independent study materials.

Anticipated Results/Potential Commercial Applications as described by the awardee: The nuclear physics encyclopedia has significant commercial value. High schools and colleges will have a practical method of introducing the concepts of nuclear physics. It will enhance institutions with nuclear physics courses by providing an innovative method of presenting and learning key concepts. National Laboratories and other institutions will be able to use components of the nuclear physics encyclopedia to present the fundamentals of radiological training.

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A Multimedia Tutorial for Charged-Particle Beam Dynamics--WhistleSoft, Inc., 168 Dos Brazos, Los Alamos, NM 87544-2431; (505) 662-7309
Dr. Richard K. Cooper, Principal Investigator
Dr. Richard R. Silbar, Business Official
DOE Grant No. DE-FG05-94ER81900
Amount: $749,855

Charged-particle beams are the basis of an important and rapidly growing component of the U.S. economy. Industries which are built on the physics of charged-particle beams include those making TV tubes, x-ray machines, medical accelerators for the treatment of cancer, electron microscopes, and electron beams for lithography and precision welding. Equally important to the Nation is the likelihood that future supplies of tritium, an unstable element of critical importance to our National defense, will be produced not by nuclear reactors, but by high-intensity proton accelerators. Similar accelerators may also be designed and built to transform transuranic wastes into short-lived or stable isotopes, easing the environmental problems associated with these by-products of the Cold War. Using the latest multimedia technology, now widely available, this project will develop appropriate tutorial materials for beam dynamics. Topics covered include beam generation, transport and focussing, and acceleration. In Phase I, a prototype tutorial was constructed. It consists of a navigational framework with 43 topic pages, covering some basic beam dynamics and materials on three kinds of focussing devices. A beam optics educational system will be delivered both for IBM compatibles running Windows and for Macintosh computers. In Phase II, the tutorials will be produced in several versions, each with a compact disk-read only memory (CD-ROM) containing programs and files executable on either platform. A hard-copy manual/workbook will accompany the CD-ROM, giving the student supplementary information keyed to the computer-based tutorial, as well as exercises which will test mastery of the material.

*Anticipated Results/Potential Commercial Applications*as described by the awardee: Charged-particle beams provide significant economic, defense, and environmental benefits. In the educational arena, this tutorial should complement, and perhaps even replace, existing textbooks on beam optics and would be available to a significantly larger market including advanced high school students to engineering professionals.

TECHNOLOGY AND INSTRUMENTATION FOR HIGH ENERGY ACCELERATORS

71

A High-Yield and Low-Emittance Positron Source from Coherent Laser-Electron Collisions--Duly Research, Inc., 1912 MacArthur Street, Rancho Palos Verdes, CA 90732; (310) 548-7123
Dr. David U. L. Yu, Principal Investigator
Dr. David U. L. Yu, Business Official
DOE Grant No. DE-FG03-94ER81740
Amount: $749,508

This project will develop a novel high-yield positron source based on coherent pair creation from the collision of a high-power laser beam with a high energy electron beam. Laser-produced positrons will have low transverse emittance and a narrow spectrum much below the primary electron beam energy. By avoiding the use of a solid target, problems associated with conventional Bethe-Heitler sources are eliminated. Spin-dependent laser effects promise to provide a natural polarization and polarization-separation of the positrons. In Phase I, analytical formulae were developed and coded to create a Monte Carlo Collision-Simulation Code. In Phase II, the code will be used to identify realistic laser parameters that would optimize the produced positron beam for a Next Linear Collider type electron beam. A device will be built and tested which will allow a single laser pulse to interact with multiple electron bunches to increase yield. Positron extraction from the collision-caused shower as well as laser pulse recycling for a multibunched linear accelerator pulse, will be modeled and optimized. In addition, this code will be used to analyze data from an ongoing Stanford Linear Accelerator experiment.

Anticipated Results / Potential Commercial Applications as described by the awardee: The planned high-yield, low-emittance, narrow-spectrum, polarized positron source should reduce system cost and complexity in achieving the high luminosity necessary in future linear colliders. The polarized positrons can probe important aspects of high energy physics. Other applications of this research include production of high energy gamma rays from laser-electron interactions for future gamma-gamma colliders, as well as production of x-rays for medical, research and industrial uses.

72

A Gatling Micro Pulse Gun for Microwave Frequency Multiplying--FM Technologies, Inc., 10529-B Braddock Road, Patriot Square, Fairfax, VA 22032-2236; (703) 425-5111
Dr. Frederick M. Mako, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG05-94ER81766
Amount: $749,982

The development of high-current short-duration pulses of electrons has been a challenging problem for many years. High-current pulses are widely used in injector systems for electron accelerators in both industrial linacs and high-energy accelerators for linear colliders. Proof-of-principle experiments are planned to validate a new concept for a micro-pulse electron source for a frequency-multiplying, high-power microwave generator. The concept utilizes a rotating cavity mode to generate a series of azimuthally distributed, bunched electron pulses and is, therefore, similar to a Gatling gun. The Gatling micro-pulse gun (GMPG) depends on resonant amplification of electron current by secondary emission from prescribed emission areas in the input radio-frequency (rf) cavity. In Phase I, the analytic theory was developed, and extensive 2 1/2-D and 3-D particle-in-cell simulations were performed. The effects of space-charge and emittance growth from all important components were examined, and a comprehensive study of several potentially promising output cavity modes was performed, which included mode competition. The results indicated that emittance growth and bunch expansion throughout the system is tolerable. In Phase II, an experimental verification of the GMPG will be conducted including input power requirements, micro-pulse duration and expansion, current density, and post-acceleration.

Anticipated Results / Potential Commercial Applications as described by the awardee: This Gatling high-current, micro-pulse electron gun will provide a high peak power, multi-kiloampere, multi-bunch picosecond-long electron source which is suitable for high-power, high-frequency rf generators. Of particular interest are 10 to 20 GHz rf generators for the next linear collider or super-power nanosecond radar.

73

A Radio Frequency Chopped, Low Emittance High Voltage Electron Source for a 30 MeV, Picosecond Bunch, High Gradient 17 Gigahertz Accelerator--Haimson Research Corporation, 3350 Scott Boulevard, Building 60, Santa Clara, CA 95054-3122; (408) 988-6007
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-94ER81774
Amount: $748,800

This project addresses the design and development of a high resolution, low emittance, picosecond bunch, 30 MeV electron source for advanced accelerator research applications. The demonstration of a high resolution 17 GHz linac beam having picosecond bunch performance with $>10^8$ electrons per bunch depends critically on the availability of a high quality electron injection system capable of producing short bunches at 17 GHz with low momentum spread for injection into the linac. Phase I indicated that a suitably designed 550 kV electron gun in combination with a 17 GHz chopper/prebuncher system could produce fully gated <20° radio frequency bunches of low emittance and low momentum spread to match the injection requirements of a 15:1 bunch compression 17 GHz high gradient accelerator structure presently under construction. The primary objectives of Phase II are (1) the detailed design and fabrication of a 550 kV demountable electron gun and a 17 GHz chopper/prebuncher system, including the associated WR62 rectangular waveguide, water cooling and vacuum systems, and (2) the installation of this equipment in a radiation shielded test facility with an existing 17 GHz high power traveling wave relativistic klystron and a 30 MeV high gradient accelerator and spectrometer system. A further objective of Phase II is to conduct a series of experiments to investigate the high resolution, picosecond bunch characteristics of the accelerated beam to evaluate the potential of this unique 17 GHz linac system as a 15 to 30 MeV electron source for advanced accelerator research applications.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that Phase II will result in the fabrication of a low emittance, high voltage (HV) injection system and the demonstration of picosecond bunch operation with a prototype 17 GHz, 30 MeV electron source suitable for advanced accelerator applications and linear collider research. The Phase II development of a demountable HV electron gun will also result in a unique commercial product for use in a wide range of high power beam devices.

74

An Efficient Higher Order Multi-Mode High Power Microwave Amplifier--Haimson Research Corporation, 3350 Scott Boulevard, Building 60, Santa Clara, CA 95054-3122; (408) 988-6007
Dr. Jacob Haimson, Principal Investigator
Ms. Beverly L. Mecklenburg, Business Official
DOE Grant No. DE-FG03-94ER81775
Amount: $746,842

A much higher efficiency radiofrequency (RF) source would have a beneficial impact on linear collider technology. However, in the development of high peak power relativistic klystrons for 11.4 and 14 GHz linear colliders, no tubes have demonstrated efficiencies of greater that 47%, and the majority have operated at less than 40%. In recognition of the potential limitation of these velocity modulation tubes, there is considerable incentive to explore new approaches for the high efficiency transfer of power from an electron beam to a coherent flux of accessible high frequency electromagnetic energy. Phase I established phase orbit data and microwave parameters for a new type of RF generator which uses a spatiotemporal modulated high power electron beam. In Phase II, the generator will be designed and fabricated. Some of the limitations associated with fast wave devices will be avoided by operating at moderate values of transverse momentum, by aggressive suppression of multipactor, and by using a relatively large, higher order multi-mode output circuit to minimize dissipation and electric field intensities. The tube, along with associated magnetics and diagnostics, will be installed in an existing test facility, and a series of high power RF tests will be conducted to evaluate the performance of this new X-band amplifier.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that Phase II will result in the design and prototype fabrication of a new high efficiency microwave tube suitable for linear collider research, and commercial applications that would benefit from a high efficiency source of RF power.

75

Improvement in the Characteristics of Ternary Niobium (Nb) Titanium (Ti) Tantalum (Ta) Alloys--IGC Advanced Superconductors, Inc., 1875 Thomaston Avenue, Waterbury, CT 06074; (203) 753-5215
Dr. Eric Gregory, Principal Investigator
Mr. B. A. Zeitlin, Business Official
DOE Grant No. DE-FG02-94ER81785
Amount: $750,000

The overall objective of Phase II will be to carry out a comprehensive investigation of multifilamentary materials containing niobium-titanium-tantalum (NbTiTa) alloys to maximize the advantages that these materials offer over conductors containing NbTi binary alloys. There is need for a material which can be made reliably in long piece lengths and with higher current densities (J_cs) at higher magnetic fields, for operation in the most demanding situations to be encountered in the Large Hadron Collider (LHC) at CERN and upgrades of other accelerators. There is also a similar need for material for many commercial applications. In Phase I a binary alloy containing 47.5 wt % Ti was compared with three ternary alloys. The upper critical field (H_{c2}) as determined by extrapolation of J_c vs. field data at 4.2 K and 2.0 K and the critical temperatures (T_cs) of all these alloys were determined. The J_c versus field characteristics at 4.2 K and 2.0 K were compared with materials heated in several different ways, and an attempt was made to relate these to the amount of alpha-phase Ti produced. In Phase II, the understanding of the relationship between structure and properties will be explored, and the heat treatments on the ternary compositions containing the lower Ti contents will be optimized. The already fabricated billet, and small billets of other compositions yet to be made, will be used to produce more material and refine the composition further. A more comprehensive investigation will be carried out on H_{c2}s, T_cs, and J_cs determined after various treatments to select the most suitable alloy and heat treatment for J_c performance at low temperatures and high fields. When the ideal composition and heat treatment cycle is determined, a full-sized billet will be made using an alloy of the chosen composition.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project is expected to result in the development of a higher J_c material for accelerator magnets, particularly those to be used in relatively low temperature and high field environments, such as those existing in the LHC. Examples of these are low beta quadrupoles and high field dipoles for sharp bending of the beam, such as is required to direct the beam inside the accelerator ring. In many of these applications high radiation levels are encountered. The A-15 type materials suffer degradation under these conditions whereas the ternary NbTi-based materials are relatively unaffected. Ductility problems are also far less in the latter than in materials such as niobium tin.

76

A Porous Metal Cooled Klystron Collector--Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601-4794; (717) 569-6551
Mr. John H. Rosenfeld, Principal Investigator
Mr. Richard W. Longsderff, Business Official
DOE Grant No. DE-FG05-94ER81889
Amount: $744,930

The B-Factory klystron depressed collector, under development at the Stanford Linear Accelerator Center (SLAC), needs to operate at heat fluxes of up to 1500 W/cm^2 without exceeding a collector surface temperature of about 250°C and with acceptable coolant flow rate and pressure drop. The objective of this project is to demonstrate the capability of porous metal cooling to effectively remove heat absorbed by depressed collectors of high power klystrons and gyrotrons. In Phase I, a preliminary design for a porous metal-cooled klystron collector was completed, and test data were collected on a representative segment test article using water as a coolant. It was found that a porous metal cooled klystron collector could be designed with flow and pressure drop requirements comparable to those of present single-phase channel-cooled designs, while providing an additional margin for maximum operating surface temperature. A representative segment article was designed, built, and tested using the specifications resulting from the design study. Phase I showed the promise of a porous metal-cooled klystron collector to meet the SLAC high energy cooling needs, as well as for related applications such as accelerator production of tritium (APT) klystron and gyrotrons. In Phase II, applications will be developed for the SLAC high energy klystron multi-staged depressed collector, the APT klystron collector, a next-generation gyrotron depressed collector, and a commercial derivative low-cost version of the technology for the refrigeration industry. Requirements will be defined and a design completed for each application. Phase II will also include the development of supporting assembly and advanced materials fabrication technology, assembly of the heat exchanger/collector, and testing.

Anticipated Results / Potential Commercial Applications as described by the awardee: Successful completion of this project should benefit the accelerator community because reliable operation of klystrons with collector heat fluxes of over 1000 W/cm^2 will be possible for the first time. Depressed collector technology for the next generation of gyrotrons will be demonstrated, and low cost, enhanced performance commercial heat exchangers using porous metal technology should be available immediately. Applications also exist for cooling of solid-state electronics, fusion energy components, and aerospace components.

HIGH ENERGY PHYSICS DATA PROCESSING AND DETECTOR INSTRUMENTATION

77

Reliable Large-Area Avalanche Photodiodes (APDs) for Improved Calorimetry--Advanced Photonix, Inc., 1240 Avenida Acaso, Camarillo, CA 93012-8754; (805) 987-0146
Mr. John Montroy, Principal Investigator
Mr. S. C. Han, Business Official
DOE Grant No. DE-FG03-94ER81697
Amount: $749,869

Large area avalanche photodiodes (LAAPDs) are uniquely sensitive semiconductor detectors that have a host of applications in high energy physics (HEP) experiments. These high voltage devices need to survive for several years in harsh radiation environments to be effective alternatives to the photomultiplier tubes that are presently used. The present LAAPD lifetime in a benign environment is limited to less than 1000 hr, and the lifetime in heavy particle environments has been found to be on the order of hours. The limited data collected to date indicate that the same mechanism is responsible for catastrophic device failure in both environments. These data also indicate that specific biasing circuitry, device design, and semiconductor processing improvements can be utilized to fabricate radiation-hardened LAAPDs. In Phase I, the ultraviolet (UV) response of LAAPDs was increased by a factor of six at 300 nm, making these devices an attractive option for many HEP calorimetry applications where scintillator materials emit in the UV and blue regions of the optical spectrum. In Phase II, the reliability of UV-enhanced LAAPDs in a calorimeter environment will be addressed. Several innovative approaches based on recent advances in silicon materials growth and fabrication technologies will be explored. Throughout the project a statistical process control system will be utilized to assess the progress towards fabrication of LAAPDs with mean-time-to-failure of 100,000 hr.

Anticipated Results / Potential Commercial Applications as described by the awardee: The project will increase the reliability of LAAPDs in both benign and radiation environments. Reliable LAAPDs can be used at installations such as the Stanford Linear Accelerator Center, the Fermi National Accelerator Laboratory, and the Centre European pour Recherche Nuclear. Commercial applications include positron emission tomography scanners, spectroscopy instruments, color processing equipment, and inspection systems.

NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

78

Jet Vapor Deposition of Multilayer and Nanocluster Thick Film Targets for Radioactive Nuclear Beams and Medical Applications--Jet Process Corporation, 25 Science Park, New Haven, CT 06511-1968; (203) 786-5130
Dr. Bret L. Halpern, Principal Investigator
Mr. Jerome J. Schmitt, Business Official
DOE Grant No. DE-FG05-94ER81793
Amount: $750,000

This project concerns the use of a jet vapor deposition (JVD) process to deposit multilayer, thick film, recoil release targets for radioactive nuclear beam (RNB) production. RNBs are critical research tools in nuclear and astrophysics, studies of materials, and medical research. However, target design is critical to assure high RNB intensity and stable operation, and a need exists for efficient beam targets. The innovative feature of the JVD process is its use of supersonic jets in low vacuum for localized deposition of atoms and molecules. Deposition rates are extremely high, and multilayer and cluster films are easily made with near zero waste of expensive isotopically enriched species. In Phase I, the JVD process was used to make multilayer titanium nitride/carbon ($Ti^{15}N/C$) nanoscale targets which, under high energy bombardment, gave a carbon monoxide ($C^{15}O$) production rate 100 times higher than previously achieved. Target design is also critical for production of radioisotopes used for medical diagnostics, such as positron emission tomography (PET), and in diagnostic or therapeutic procedures involving radioisotope-labelled monoclonal antibodies. In Phase II $Ti^{14,15}N/C$ targets for production of $C^{14,15}O$ will be optimized, and nanoporous cluster targets of aluminum oxide ($Al_2{}^{17,18}O_3$) will be developed. Two kinds of target will be made for medical applications: (1) thick films of bismuth (Bi) or Bi oxide for astatine (^{211}At), and thick films of tellurium (Te) for iodine (^{124}I), both used in labelled monoclonal antibody therapy and (2) two-phase porous carbon targets for PET applications of ^{11}C, nitrogen (^{13}N), ^{15}O, and fluorine (^{18}F). Success in Phase II will provide the nuclear physics community with a reliable, economical source of high quality targets capable of generating a variety of RNB species.

Anticipated Results/Potential Commercial Applications as described by the awardee: The anticipated benefits are: development of efficient, economical techniques for fabrication of thin film RNB and medical radioisotope targets, establishment of a stable supplier, economic production of specific targets needed in nuclear physics research, PET, and other medical applications, and reduction of health care costs for radioisotope diagnostics and therapy.

79

Low Cost Substrates for Micro-Strip Gas Chambers--Surmet Corporation, 33 B Street, Burlington, MA 01803-3406; (617) 272-3250
Mr. Richard A. Cooke, Principal Investigator
Dr. Suri A. Sastri, Business Official
DOE Grant No. DE-FG02-94ER81876
Amount: $750,000

Micro-Strip Gas Chambers (MSGC) are versatile devices for detecting particles in high energy accelerators. They are of great interest because of their fine granularity, high gain, high counting rates, potential for low cost, and large area event detection. MSGC have been demonstrated by several research and industrial concerns, and the early results suggest that large area (250 mm x 180 mm) devices can be manufactured that will satisfy many research and commercial needs. Manufacturing of MSGC follows the methods in the microelectronics industry with thin-film technology and microlithography playing key roles in depositing patterned metal films on insulating substrates. A key requirement for MSGC substrates is a surface resistivity in the 10^{13} to 10^{16} ohms/square range to reduce surface charging at high count rates and to improve long-term stability. Achieving this surface resistivity has proven to be a technical challenge. A low-cost, multilayered, thin-film structure will be developed to provide a substrate with a surface resistance that is controllable in the 10^{12} to 10^{15} ohms/square range. In Phase I, substrates up to 200 mm x 280 mm were coated with excellent uniformity. Excellent adherence of the metal electrodes to the resistive surfaces was observed and overcoating to prepatterned MSGC was also demonstrated. In Phase II, the long term stability of the coating under high rate x-ray exposure will be tested, and the coating as a surface resistivity modification method will be evaluated. MSGC will be built and tested at high count rates and the aging and performance characteristics will be evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: MSGC are important new detectors for high rate, high resolution particle counting. Major international experiments such as the Continuous Electron Beam Accelerator Facility and the Large Hardon Collider at CERN will require such a device to meet their research goals. MSGC could provide a key technology to enable low-cost, large area device manufacture in the commercial development of improved medical and biological x-ray detectors with higher resolution, lower dose, and direct digital imaging.

NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

80

A High Power Solid State Amplifier--Amparo Corporation, 119 East Marcy Street, Suite 110, Santa Fe, NM 87501; (505) 982-6742
Dr. Don W. Reid, Principal Investigator
Dr. James J. Walker, Business Official
DOE Grant No. DE-FG05-94ER81703
Amount: $750,000

During the past ten years significant progress has been made in the radio frequency (rf) power handling capabilities of solid state devices. These developments have led to suggestions that solid state rf power amplifiers might even invade the domain of gridded tubes and klystron applications. In Phase I, a solid state amplifier for fixed frequency operation at a nominal center frequency of 1500 MHz was designed with an output power of five kW, a minimum gain of 35 dB, and an efficiency greater than 40%. The amplifier developed during Phase I had a minimum overall efficiency of 45% and a gain of 38 dB. In Phase II, the design will be completed and a prototype will be fabricated. The prototype will be tested at the Continuous Electron Beam Accelerator Facility (CEBAF) in an actual klystron socket to demonstrate performance. A parallel effort will be undertaken to design an amplifier which will address cost minimization and commercialization of the product. The first goal of the Phase II project, in addition to advancing the state-of-the-art for L-band solid state amplifiers, is to develop a prototype that is interchangeable with the klystrons used at present in the CEBAF accelerator.

Anticipated Results/Potential Commercial Applications as described by the awardee: The successful development of this solid state rf power amplifier should allow commercialization in frequencies from ultrahigh to S-band. Replacing klystrons and gridded tubes with solid state devices promises better reliability and longer component life which are important factors in the communication industry.

81

A Framework for a General Purpose Intelligent Control System for Particle Accelerators--Vista Control Systems, Inc., 134-B Eastgate Drive, Los Alamos, NM 87544-3304; (505) 662-2484
Dr. Robert T. Westervelt, Principal Investigator
Mr. Peter N. Clout, Business Official
DOE Grant No. DE-FG05-94ER81897
Amount: $750,000

Accelerator control systems have long applied advanced computing technologies to the demanding requirements of state-of-the-art physics research facilities. In theory, an intelligent accelerator control system should improve efficiency, maintainability, and delivery of beam on target. However, intelligent control systems have lagged behind other state-of-the-art computing technologies for a variety of reasons. Computing power has until recently been insufficient to meet accelerator control demands and the complexity of the problems encountered in controlling large accelerator facilities was typically too great for a general-purpose, intelligent control system to address fully. Recent advances in computer hardware and control software performance and capabilities have lifted these limitations and made it possible to develop advanced systems providing cost-effective, intelligent accelerator control. This project will develop a general purpose, intelligent control system for use in accelerator facilities. In Phase I, different tuning problems proved amenable to different types of solution strategies. Some techniques were shown to work well for some problems and poorly for others. An expert system could chose, from a supported set of heuristics, the method best suited to solve the current control problem. Phase II will develop, test, and distribute a complete prototype for an intelligent accelerator control system. The intelligent controller will be tested under actual operating conditions at representative accelerator facilities. Data on operations from these facilities will be used to develop and fine-tune the heuristic control techniques. The set of control scenarios, developed during Phase I, will be codified for distribution among the accelerator controls and artificial intelligence communities. The scenarios developed will include simple steering, periodic lines, matching beam transformer, general matching and the achromatic bend. We expect these scenarios to provide a common frame of reference for work on advanced accelerator control systems.

Anticipated Results/Potential Commercial Applications as described by the awardee: The result of the project will be a viable prototype for an intelligent control system for particle accelerators. This prototype will serve as the basis for the development of a commercially available general purpose intelligent control system. This general purpose intelligent control system will be useful in a wide range of industrial control applications.

APPENDIX A

Alphabetical List of Awardees

Abacus Controls, Inc. ***1***
Mr. George A. O'Sullivan, Business Official
P.O. Box 893
Somerville, NJ 08876-0893
(908) 526-6010

Acrion Technologies, Inc. ***25***
Dr. William R. Brown, Business Official
9099 Bank Street
Cleveland, OH 44125-3436
(216) 573-1187

Advanced Energy Systems, Inc. (formerly Solar Design Associates ***2***
Mr. Steven J. Strong, Business Official
P.O. Box 242
Harvard, MA 01451-0242
(508) 456-6855

Advanced Fuel Research, Inc. ***49***
Dr. David G. Hamblen, Business Official
87 Church Street
P.O. Box 380379
East Hartford, CT 06138-0379
(203) 528-9806

Advanced Modular Power Systems, Inc. ***43***
Dr. Thomas K. Hunt, Business Official
4667 Freedom Drive
Ann Arbor, MI 48108-9784
(313) 677-4260

Advanced Photonix, Inc. ***77***
Mr. S. C. Han, Business Official
1240 Avenida Acaso
Camarillo, CA 93012-8754
(805) 987-0146

Aerodyne Research, Inc. ***55***
Dr. Charles E. Kolb, Business Official
45 Manning Road
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(508) 663-9500

Aerometrics, Inc. ***18***
Dr. William D. Bachalo, Business Official
550 Del Rey Avenue, Unit A
Sunnyvale, CA 94086-3528
(408) 738-6688

AeroVironment, Inc. ***7***
Mr. Thomas Zambrano, Business Official
222 East Huntington Drive
Monrovia, CA 91016-3500
(818) 357-9983

Amparo Corporation ***80***
Dr. James J. Walker, Business Official
P.O. Box 2687
Santa Fe, NM 87504-2687
(505) 982-6742

Anatole J. Sipin Company, Inc. ***40***
Mr. A. J. Sipin, Business Official
505 Eighth Avenue
New York, NY 10018-6505
(212) 695-5706

Andcare, Inc. ***53***
Mr. John P. O'Daly, Business Official
2810 Meridian Parkway, Suite 152
Durham, NC 27713-2277
(919) 544-8220

Apfel Enterprises, Inc. ***13***
Mr. Robert E. Apfel, Business Official
25 Science Park, Suite 676
New Haven, CT 06511-1968
(203) 786-5599

Aspen Systems, Inc. ***4***
Dr. Kang Lee, Business Official
184 Cedar Hill Street
Marlborough, MA 01752-3017
(508) 481-5058

BIODE, Inc. ***10***
Dr. Douglas McAllister, Business Official
2 Oakwood Road
Cape Elizabeth, ME 04107-2025
(207) 883-1492

Blasch Precision Ceramics, Inc. ***19***
Mr. David W. Bobrek, Business Official
580 Broadway
Albany, NY 12204-2802
(518) 436-1263

References denote award numbers

Busek Company, Inc. ***34***
Mrs. J. Budny, Business Official
11 Tech Circle
Natick, MA 01760-1023
(508) 655-5565

Cambridge Hydrodynamics, Inc. ***15***
Ms. R. Karp, Business Official
P.O. Box 1403
Princeton, NJ 08542-1403
(609) 683-1515

Charles Evans and Associates ***20***
Mr. James E. Plank, Business Official
301 Chesapeake Drive
Redwood City, CA 94063-4723
(415) 369-4567

Conductus, Inc. ***52***
Dr. Duane B. Crum, Business Official
10623 Roselle Street
San Diego, CA 92121-1506
(619) 550-2700

Containerless Research, Inc. ***50***
Dr. Paul C. Nordine, Business Official
910 University Place
Evanston, IL 60201-3149
(708) 467-2678

Correlations Company (formerly
NW Resources) ***26***
Mr. Bill Weiss, Business Official
P.O. Box 187
Socorro, NM 87801-0187
(505) 835-5220

Cryogenic Applications F, Inc. ***59***
Dr. Christopher A. Foster, Business Official
450 Bacon Springs Lane
Clinton, TN 37716-5311
(615) 435-5433

Duly Research, Inc. ***71***
Dr. David U. L. Yu, Business Official
1912 MacArthur Street
Rancho Palos Verdes, CA 90732
(310) 548-7123

EDTEK, Inc. ***37***
Mr. William E. Horne, Business Official
14704 Southeast 100th Street
Renton, WA 98059-3750
(206) 235-5163

EIC Laboratories, Inc. ***45***
Dr. A. C. Makrides, Business Official
111 Downey Street
Norwood, MA 02062-2668
(617) 769-9450

Electronic Power Conditioning, Inc. ***8***
Mr. Dallas A. Marckx, Business Official
1895 Northwest 9th Street, Suite A
Corvallis, OR 97330-2144
(503) 753-7220

Eltron Research, Inc. ***27, 28, 39***
Ms. Eileen E. Sammells, Business Official
2830 Wilderness Place, #E
Boulder, CO 80301-5455
(303) 440-8008

Energy Research Corporation ***29***
Dr. H. C. Maru, Business Official
3 Great Pasture Road
Danbury, CT 06813
(203) 792-1460

Envirogen, Inc. ***56***
Mr. William J. Guarini, Business Official
4100 Quakerbridge Road
Lawrenceville, NJ 08648-4702
(609) 936-9300

Environmental Elements Corporation ***21***
Dr. Paul L. Feldman, Business Official
3700 Koppers Street
P.O. Box 1318
Baltimore, MD 21203
(410) 368-7239

EXPORTech Company, Inc. ***16***
Mrs. Marcia R. Oder, Business Official
P.O. Box 588
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(412) 337-4415

FM Technologies, Inc. ***72***
Dr. Frederick M. Mako, Business Official
10529-B Braddock Road
Patriot Square
Fairfax, VA 22032-2236
(703) 425-5111

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JX Crystals, Inc. ***44***
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APPENDIX B

State List of Awardees

California 3, 7, 9, 18, 20, 23, 31, 38, 41, 47, 52, 54, 58, 64, 66, 67, 69, 71, 73, 74, 77
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DEPARTMENT OF ENERGY

SBIR

1996

PHASE I

AWARDS

DEPARTMENT OF ENERGY
SMALL BUSINESS INNOVATION RESEARCH PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1996 AWARDS

TOPIC: ADVANCED FOSSIL FUELS RESEARCH

CeraMem Corporation 12 Clematis Avenue Waltham, MA 02154-7035	Catalytic Membrane for High Temperature Hydrogen Separations
Mineral Technologies International, Inc. 1219 Downwood Manor Morgantown, WV 26505-8677	An Integrated Process for Recovery of Coal Fines from Waste Streams

TOPIC: NATURAL GAS UTILIZATION

Advanced Fuel Research, Inc. P.O. Box 380379 87 Church Street East Hartford, CT 06138-0379	Sensors for Performance Monitoring of Advanced Gas Turbines
Bend Research, Inc. 64550 Research Road Bend, OR 97701-8599	Thermally Stable Nitrogen-Absorbents
Endesco Services, Inc. 1700 South Mount Prospect Road Des Plaines, IL 60018-1800	An Innovative Hybrid Process for the Economical Upgrading of Raw Natural Gas to Pipeline Quality
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06810-8152	Innovative Carbonate Fuel Cell Design to Reduce Carbonate Vaporization Loss
Energy Research Corporation 3 Great Pasture Road Danbury, CT 06810-8152	Low Cost, Environmental Friendly Carbonate Fuel Cell Matrix Fabrication
M-C Power Corporation 8040 South Madison Street Burr Ridge, IL 60521-5808	High Speed Manufacturing for Molten Carbonate Fuel Cell Components
M-C Power Corporation 8040 South Madison Street Burr Ridge, IL 60521-5808	Improved Sealing Molten Carbonate Fuel Cell Electrolyte Matrix

Materials and Systems Research, Inc. 62 East Cleveland Avenue Salt Lake City, UT 84115-5328	Intermediate Temperature (~650 Degrees Celsius), High Power Density Solid Oxide
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025-1516	Control of Glycol Dehydrator Benzene, Toluene, Ethylbenzene, and Xylene Emissions
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025-1516	High Performance Membranes for Removal of Carbon Dioxide from Natural Gas
NexTech Materials, Ltd. 720 Lakerview Plaza Boulevard Suite I Worthington, OH 43085-4733	Composite Ceria Eletrolytes for Solid Oxide Fuel Cells
Northwest Fuel Development, Inc. 4064 Orchard Drive Lake Oswego, OR 97035-2406	Nitrogen Selective Adsorption for Natural Gas Upgrading
Spectral Sciences, Inc. 99 South Bedford Street #7 Burlington, MA 01803-5153	Automated Optical BTU (British Thermal Unit) Sensor for the Natural Gas Industry

TOPIC: ADVANCED OIL AND GAS TECHNOLOGY

Electromagnetic Instruments, Inc. P.O. Box 463 El Cerrito, CA 94530-0463	Oil Field Inductive Resistivity Logging in Steel-Cased Wells
TomoSeis, Inc. 1650 West Sam Houston Parkway North Houston, TX 77043-3115	Semiconductor Strain Gauge Based Pressure Transducer for Use in Borehole Seismics
TomoSeis, Inc. 1650 West Sam Houston Parkway North Houston, TX 77043-3115	Finite Element Modeling of Downhole Sources and Receivers

TOPIC: ADVANCED COAL-BASED POWER SYSTEMS

Busek Company, Inc. 11 Tech Circle Natick, MA 01760-1023	Advanced Coal Based Power System Components Using Reaction Bonded Silicon Carbide
CeraMem Corporation 12 Clematis Avenue Waltham, MA 02154-7035	Gas-Solid Reaction and Separation Process for Simultaneous Removal of Toxic Metals and Particulates in Coal-Based Power Systems
Environmental Elements Corporation 3700 Koppers Street Baltimore, MD 21227-1087	Advanced Laminar Flow Wet Electrostatic Precipitator
Intercat Development, Inc. P.O. Box 412 Sea Girt, NJ 08750-0412	An Attrition-Resistant Zinc Titante Sorbent for a Transport Reactor
Ion Physics Corporation 11 Industrial Way Atkinson, NH 03811-2195	Control of Respirable Particulate Matter from Flue Gases
RoadRunner Ceramics, Inc. 78 Ida Court Corrales, NM 87048-8598	Corrosion-Resistant Porous Ceramics for Hot Gas Filter Applications

TOPIC: NOVEL AND IMPROVED MATERIALS AND SENSORS FOR THE GLASS INDUSTRY

Karta Technology, Inc. 1892 Grandstand San Antonio, TX 78238-4507	Noncontact Viscosity Measurement of Molten Glass Using Laser-Generated Ultrasound for Process Control During Melting and Forming Operations
Mission Research Corporation 735 State Street P.O. Drawer 719 Santa Barbara, CA 93101-3351	A Light Scattering Based Sensor for On-Line Monitoring of Fiber Diameter Distribution During Fiberglass Manufacturing
Ultramet 12173 Montague Street Pacoima, CA 91331-2210	Advanced Materials for Higher Temperature Glass Forming

TOPIC: PHOTOVOLTAIC MODULE MANUFACTURING PROCESSES AND SYSTEM COMPONENTS RESEARCH AND DEVELOPMENT

Advanced Energy Systems, Inc. P.O. Box 262 Wilton, NH 03086-0262	Module Integrated Maximum Power Point Tracking Charge Controllers - The Missing Link in Large Scale Photovoltaic Systems
Energy Conversion Devices, Inc. 1675 West Maple Road Troy, MI 48084-7118	Novel Use of Gas Jet Plasma to Prepare Amorphous Silicon Alloy
Energy Photovoltaics, Inc. 276 Bakers Basin Road Lawrenceville, NJ 08648-3312	High Rate Deposition of Transparent Conducting Zinc Oxide Using Activated Oxygen for Photovoltaic Manufacturing Cost Reduction

TOPIC: MOTORS, SWITCHES, AND SENSORS FOR HYBRID ELECTRIC VEHICLE TECHNOLOGY

SatCon Technology Corporation 161 First Street Cambridge, MA 02142-1207	Innovative Bonding and Spray-Forming Techniques for Cost-Effectively Producing High Performance Induction Motors
Sensor Research and Development Corporation P.O. Box 191 Orono, ME 04473-0191	Tungsten Trioxide Films for Detection of Nitrogen Oxide in Automotive Exhaust Streams
Southwest Sciences, Inc. 1570 Pacheco Street Suite E-11 Santa Fe, NM 87505-3987	A Real Time Hydrocarbon Emissions Sensor for Hybrid Electric Vehicles

TOPIC: FUEL CELLS FOR BUILDING APPLICATIONS

EIC Laboratories, Inc. 111 Downey Street Norwood, MA 02062-2664	Carbon Monoxide Tolerant Anodes for Proton Exchange Membrane Fuel Cells
Lynntech, Inc. 7610 Eastmark Drive Suite 105 College Station, TX 77840-4023	Novel Proton Exchange Membrane for Fuel Cell Application
Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706-9237	Low Cost Advanced Bipolar Plates for Proton Exchange Membrane Fuel Cells

Mechanical Technology, Inc. 968 Albany-Shaker Road Latham, NY 12110-1401	Natural Gas Reformer Cleanup System for Proton Exchange Membrane Fuel Cells

TOPIC: HIGH TEMPERATURE SUPERCONDUCTIVITY FOR ENERGY APPLICATIONS

American Superconductor Corporation Two Technology Drive Westborough, MA 01581-1727	Improved Bismuth-2223 Flux Pinning Through Chemical Doping
American Superconductor Corporation Two Technology Drive Westborough, MA 01581-1727	Low Cost Multifilament Composite Process
American Superconductor Corporation Two Technology Drive Westborough, MA 01581-1727	High Temperature Superconducting Composites With Low Alternating Current Loss

TOPIC: CHARACTERIZATION, MONITORING, AND SENSORS FOR THE GLASS INDUSTRY

Detection Limit, Inc. P.O. Box 130 Laramie, WY 82070-0130	A Sensor for In-Situ Detection, Identification, and Quantification of Trichloroethylene for Cone Penetrometers
Physical Optics Corporation 20600 Gramercy Place Suite 103 Torrance, CA 90501-1821	Cone Pentrometer Deployable Solid Phase Optical Chemical Sensor for Subsurface Detection of Halohydrocarbons
Physical Sciences, Inc. 20 New England Business Center Andover, MA 01810-1022	Real Time Monitor for the Laser-Based Coatings Removal System

TOPIC: CHEMICAL SEPARATION PROCESSES FOR WASTE TREATMENT

American Research Corporation of Virginia P.O. Box 3406 Radford, VA 24143-3406	Template-Medicated Synthesis of Periodic Membranes for Improved Liquid-Phase Separations
Chemica Technologies, Inc. 20332 Empire Avenue Suite F-3 Bend, OR 97701-5712	Novel Fiber-Based Adsorbent Technology

ISOTRON Corporation 13152 Chef Menteur Highway New Orleans, LA 70129-1865	Recyclable Bio-Reagent for Rapid and Selective Extraction of Contaminants from Soil
Lynntech, Inc. 7610 Eastmark Drive Suite 105 College Station, TX 77840-4023	A New Separation and Treatment Method for Soil and Groundwater Restoration
Membrane Technology and Research, Inc. 1360 Willow Road Suite 103 Menlo Park, CA 94025-1516	Innovative Method to Stabilize Liquid Membranes for Removal of Radionuclides from Groundwater
TPL, Inc. 3754 Hawkins, NE Albuquerque, NM 87109-4511	Metal-Binding Silica Materials for Wastewater Cleanup

TOPIC: WASTE MANAGEMENT TECHNOLOGIES FOR MIXED LOW LEVEL WASTE

ADA Technologies, Inc. 304 Inverness Way South Suite 365 Englewood, CO 80112-5828	Continuous Analyzer for Monitoring Hydrogen Chloride/Chlorine During Site Cleanup Activity
J. and D. Scientific, Inc. 4300 NW 23rd Avenue Suite 11 Gainesville, FL 32606-6541	A Practical Laser Induced Breakdown Spectrometer for Real Time On-Line Monitoring of Aqueous Process Streams
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033-1916	A Low Cost Process for the Concentration and Stabilization of Mixed Low Level Waste

TOPIC: ADVANCED SENSORS FOR NONPROLIFERATION AND NATIONAL SECURITY

Aerodyne Research, Inc. 45 Manning Road Billerica, MA 01821-3934	A Low Level Tritium Monitor Based on a Multi-Phase Scintillator Material
Eltron Research, Inc. 5660 Airport Boulevard Boulder, CO 80301-2340	A Miniaturized Flow-Injection System for Unattended Monitoring of Uranium by Electrochemical Detection

First Point Scientific, Inc. 5300 Derry Avenue Suite J Agoura Hills, CA 91301-4501	Long-Life Electrical Neutron Generator
NAVSYS Corporation 14960 Woodcarver Road Colorado Springs, CO 80921-2370	Tracktag-A Global Positioning System/ Radio Frequency Identification Tag for Location and Status Monitoring
Randtec, Inc. 10340 Democracy Lane, Suite 202 Fairfax, VA 22030-2518	Development of a Radio Frequency Tagging Method for Use in Monitoring International Nonproliferation Treaty Compliance
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143-4228	A Compact Neutron Generator
Technology Service Corporation 2950 31st Street Santa Monica, CA 90405-3037	Synthetic Aperture Radar Motion Compensation Using Autofocus

TOPIC: ADVANCED PHYSICAL SECURITY TECHNIQUES FOR DEPARTMENT OF ENERGY NUCLEAR FACILITIES

Advanced Safeguards, Inc. 161 West Jackson Street Elmhurst, IL 60126-4857	A Reusable, Non-Toxic, Non-Lethal Activated Barrier to Delay Unauthorized Intruders by Vision Obscuration
Mandall Armor Design & Manufacturing, Inc. 901 East Madison Street Phoenix, AZ 85034-2229	High Energy Resistant, Passively Activated Barrier Construction Barrier
Scientific Applications and Research Associates, Inc. 15262 Pipeline Lane Huntington Beach, CA 92649-1136	High Intensity Acoustic Fields for Access Denial

TOPIC: TRANSMISSION, PROCESSING, AND ANALSIS OF DATA COLLECTED FOR NONPROLIFERATION APPLICATIONS

Physical Optics Corporation 20600 Gramercy Place Suite 103 Torrance, CA 90501-1821	Edge Polynomial Fractal Compression Algorithm for High Quality Video Transmission
Princeton Electronic System P.O. Box 8627 Princeton, NJ 08543-8627	Transmission of Highly Compressed Imagery in Real Time Through Satellite Channels
Ronin Systems, Inc. 23 Woodland Street New Haven, CT 06511-3544	Wavelet-Based Video Compression for Massively Parallel Processors

TOPIC: RESEARCH AND DEVELOPMENT ON HIGH PERFORMANCE COMPUTING AND INFORMATION INFRASTRUCTURE

Centric Engineering Systems, Inc 3393 Octavius Drive Suite 201 Santa Clara, CA 95054-3004	Application of High-Performance Parallel Computation to Multiphysics Simulations
Reaction Engineering International 77 West 200 South Suite 210 Salt Lake City, UT 84101-1609	A Parallel Adaptive Simulation Tool for Two Phase Steady State Reacting Flows in Industrial Boilers and Furnaces

TOPIC: INTELLIGENT SYSTEMS FOR MATERIALS SYNTHESIS AND PROCESSING, MANUFACTURING, AND ENERGY USES

Eltron Research, Inc. 5660 Airport Boulevard Boulder, CO 80301-2340	Application of Neural Network Analysis for the Intelligent Selection of Oxygen Mediating Membranes
Harvest Technology 9253 Glenoaks Boulevard Sun Valley, CA 91352-2614	Intelligent Sensing and Control System for Ethylene Production Using Laser Ultrasonic Coke Detention
Neural Applications Corporation 2600 Crosspark Road Carolville, IA 52241-3212	Intelligent Adaptive Systems for Optimal Energy Input in Steelmaking

TOPIC: MECHANICAL MINIATURIZATION AND NANOSCALE ELECTRONICS FOR ENERGY APPLICATIONS

Angstrom Devices, Inc. 2849 East Elvira Road Tucson, AZ 85706-7126	Passive Electronic Components from Nanostructured Materials
Integrated Microtransducer Electronics Corporation 1214 Oxford Street Berkeley, CA 94709-1423	Thin-Film, Micron-Scale Transformers

TOPIC: GENOME AND DNA-RELATED TECHNOLOGIES

BIOS Laboratories, Inc. Five Science Park New Haven, CT 06511-1966	Directed Multiplex DNA Sequencing by Hybridization
Molecular Dynamics 928 East Arques Avenue Sunnyvale, CA 94086-4520	Automated Flow Sequencing
Promega Corporation 2800 Woods Hollow Road Madison, WI 53711-5399	An Engineered RNA/DNA Polymerase to Increase Speed and Economy of Deoxyribonucleic Acid Sequencing

TOPIC: ADVANCED ENVIRONMENTAL MONITORING TECHNOLOGY

Giner, Inc. 14 Spring Street Waltham, MA 02154-4497	A Novel On-Line Ammonia Sensor for Energy Conversion Applications
ORDELA, Inc. 1009 Alvin Weinberg Drive Oak Ridge, TN 37830-8012	Development and Testing of Environmentally-Safe Extractive Scintillator Solutions for Alpha Spectrometry
Owen Research, Inc. 2525 Arapahoe Avenue, Suite E4-262 Boulder, CO 80302-6720	A Multicore Optical Fiber Sensor for Mass Transport and Particulates
Polestar Technologies Inc 220 Reservoir Street Suite 28 B Needham Heights, MA 02194-3133	Infrared Hollow Waveguide Organic Solvent Analyzer

TOPIC: ATMOSPHERIC MEASUREMENTS AND SAMPLING TECHNOLOGIES

Deacon Research 2440 Embarcadero Way Palo Alto, CA 94303-3313	A Stratospheric Water Vapor Microsensor
Ion Optics, Inc. 41 North Road Suite 103 Bedford, MA 01730-1037	A Simple, Inexpensive Approach to Real-Time Calibration of Radiometric Instrumentation
Optra, Inc. 461 Boston Street Topsfield, MA 01983-1237	High Altitude Water Vapor Concentration Measurement Using Diode Laser Interferometry
Physical Optics Corporation 20600 Gramercy Place Suite 103 Torrance, CA 90501-1821	Miniature Spectrometer Based on a Novel Optical Filter with Spectral Selectivity Distributed Along the Aperture
Physical Optics Corporation 20600 Gramercy Place Suite 103 Torrance, CA 90501-1821	A High Resolution Bug Eye Orientation Sensor Based on Fuzzy Optical Metrology
Physical Sciences, Inc. 20 New England Business Center Andover, MA 01810-1022	Compact, Airborne Laser Multigas Sensor
Radiometrics Corporation 2760 29th Street #200 Boulder, CO 80301-1230	Microwave Radiometer for Passively and Remotely Measuring Atmospheric Water Vapor
Southwest Sciences, Inc. 1570 Pacheco Street Suite E-11 Santa Fe, NM 87505-3987	Advanced Water Sensor for Unmanned Aerial Vehicles
The Insitu Group MP11.48 R Cook Underwood Road Underwood, WA 98651	A Miniature Powerplant for Very Small, Very Long-Range Autonomous Aircraft

TOPIC: MEDICAL APPLICATIONS

CTI, Inc. 810 Innovation Drive P.O. Box 22999 Knoxville, TN 37932-2562	A Dedicated Positron Emission Tomography Scanner for Imaging Gene Expression in Mice
Digirad 7408 Trade Street San Diego, CA 92121-2410	Solid-State Gamma Camera with Sub-Millimeter Spatial Resolution

TOPIC: PROCESSING OF THIN FILM PHOTOVOLTAIC MATERIALS AND DEVICES

Energy Photovoltaics, Inc. P.O. Box 7456 Princeton, NJ 08543	Binary-Chalcogenides as Evaporation Source Material For Copper (Indium, Gallium) (Selenide, Sulfide) Thin-Film Deposition
Green Development, LLC 16164 West 13th Place Golden, CO 80401-2983	Development of Optimal Tin Oxide Contacts for Cadmium Telluride Photovoltaic Applications
International Solar Electric Technology, Inc. 8635 Aviation Boulevard Inglewood, CA 90301-2001	Large Area, Low Cost Processing for Copper Indium Selenide Photovoltaics
UNISUN 587-F North Ventu Park Road #124 Newbury Park, CA 91320-2741	Improved Processes for Forming Copper Indium Selenide Films

TOPIC: ADVANCED INSTRUMENTATION TO EXPLOIT NEUTRON AND PHOTON SOURCES

ARACOR 425 Lakeside Drive Sunnyvale, CA 94086-4704	High-Gain Monocapillary Optics
Adherent Technologies, Inc. 9621 Camino del Sol, NE Albuquerque, NM 87111-1522	Ultrafast Polysilylene Scintillators
Hirsch Scientific 365 Talbot Avenue Suite D8 Pacifica, CA 94044-2657	High Performance X-Ray and Neutron Microfocusing Optics

NOVA Scientific, Inc. 54 Main Street Sturbridge, MA 01566-1281	Microchannel Plate Imaging Neutron Detector
Princeton Scientific Instruments, Inc. 7 Deer Park Drive Monmouth Junction, NJ 08852-1921	High Frame Rate Ultraviolet/X-Ray Imager
X-Ray Optical Systems, Inc. 90 Fuller Road Albany, NY 12205-5719	Monolithic Polycapillary Optic for Bending and Microfocusing Neutron Beams
X-Ray Optical Systems, Inc. 90 Fuller Road Albany, NY 12205-5719	Coating Capillary Optics to Improve X-ray and Neutron Transmission

TOPIC: HARD ROCK DRILLING TECHNOLOGIES

APS Technology P.O. Box Q Hellertown, PA 18055	An Autonomous Self-Propelled System for Hard Rock Drilling
Diamond Materials, Inc. 120 Centennial Avenue Piscataway, NJ 08854-3908	Superhard Nanophase Cutter Materials for Rock Drilling Applications
Kalsi Engineering, Inc. 745 Park Two Drive Sugar Land, TX 77478-2843	High Speed Bearing for Roller Cone Drill Bits Used in Hard Rock Drilling
Novatek 2185 South Larsen Parkway Provo, UT 84606-6218	Very Low Friction Small Radius Domed Cutters for Percussion Drill Bits
Novatek 2185 South Larsen Parkway Provo, UT 84606-6218	Development and Testing of a Jet Assisted Polycrystalline Diamond Drilling Bit
Novatek 2185 South Larsen Parkway Provo, UT 84606-6218	Thermally Stable Polycrystalline Diamond Cutters for Hard Rock Drilling

Quest Integrated, Inc. 21414 68th Avenue South Kent, WA 98032-2416	Fatique Weakening of Hard Rock with Cyclic Underbalanced Pressures
Science Research Laboratory, Inc. 15 Ward Street Somerville, MA 02143-4228	Advanced Low-Stress Bonding of Thermally Stable Polycrystalline Diamond Cutters to Tungsten Carbide Substrates
Spire Corporation One Patriots Park Bedford, MA 01730-2396	Nanocrystalline Superhard, Ductile Ceramic Coatings for Roller Cone Bit Bearings

TOPIC: HIGH-POWER ENERGY STORAGE DEVICES FOR TRANSPORTATION APPLICATIONS

Cape Cod Research, Inc. 19 Research Road East Falmouth, MA 02536-4440	Solid-State Ultracapacitors for Electric Vehicles and Consumer Electronics
Covalent Associates, Inc. 10 State Street Woburn, MA 01801-6820	A Four Volt per Cell Ultracapacitor with High Energy Density
EIC Laboratories, Inc. 111 Downey Street Norwood, MA 02062-2664	A High Power Battery Based on Insertion Electrodes
Electro Energy, Inc. Shelter Rock lane Danbury, CT 06810-8159	A High Power Bipolar Nickel-Metal Hydride Battery for a Hybrid Vehicle
Federal Fabrics-Fibers 21 Marie Drive Andover, MA 01810-1903	Synergetic Ultracapacitor
T/J Technologies, Inc. P.O. Box 2150 Ann Arbor, MI 48106-2150	High Surface Area Non-Oxide Ceramic Electrodes for Ultracapacitors
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033-1916	Improved Production Method for Carbon-Based Ultracapacitors

TPL, Inc. 3754 Hawkins, NE Albuquerque, NM 87109-4511	Highly Branched, Lightly Crosslinked, Solid Polymer Electrolytes
Technical Research Associates 2257 South, 1100 East Salt Lake City, UT 84106-2379	Novel Ultracapacitor Electrodes for High Power Applications

TOPIC: PLASMA CONFINEMENT SYSTEMS TECHNOLOGY

Composite Technology Development, Inc. 2400 Central Avenue, Suite H Boulder, CO 80301-2843	Wrappable Inorganic Electrical Insulators for Superconducting Magnets
Composite Technology Development, Inc. 2400 Central Avenue, Suite H Boulder, CO 80301-2843	Novel Composite Insulators for Radio-Frequency Antenna Limiters
FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236	Pulsed Induction Joining of Sapphire to Metal for Gyrotron Windows
Plasma Processes, Inc. 4914D Moores Mill Road Huntsville, AL 35811	Joining of Tungsten Armor Using Functional Gradients
Sherbrooke Consulting Inc 44 Sherbrooke Road Newton, MA 02184-5707	Modelling and Analysis of Superconducting Joints for High Field and Pulsed Applications in the International Thermonuclear Engineering Reactor
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545-3301	A Cost-Effective Technical Approach to Fabricating High Critical Current Density Bronze-Route Niobium-Titanium-Tin Superconducting Wire for Fusion Applications
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545-3301	Cabled Monofilaments for Improved Multifilament Niobium/Tin Performance and Reduced Cost

Surmet Corporation 33 B Street Burlington, MA 01803-3406	Fabrication of a Copper-Backed Beryllium Plasma Facing Component Armor with a Built-In Diffusion Barrier Structure

TOPIC: FUSION ENERGY SYSTEMS

DELTA M Corporation 1003 Larsen Drive Oak Ridge, TN 37830	Development and Evaluation of Mineral Insulated Diagnostic Probes Subjected to High Dose Neutron Irradiation
Hyper-Therm High-Temperature Composites, Inc. 18411 Gothard Street Units B and C Huntington Beach, CA 92648-1235	Evaluation and Constitutive Modeling of Unidirectional Silicon Carbide/Silicon Carbide Composites with Engineered Silicon Carbide Fiber Coatings Subjected to Neutron Irradiation
Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706-9237	Innovative Fabrication of Silicon Carbide/Silicon Carbide Composites with High Through-the-Thickness Thermal Conductivity

TOPIC: PLASMA DIAGNOSTICS

InterScience, Inc. 105 Jordan Road Troy, NY 12180-8343	A High-Performance Data Acquistion and Processing System for Spectroscopic Applications
International Radiation Detectors 2527 West 237th Street Unit B Torrance, CA 90505-5243	Silicon Detectors with 40 Angstrom Entrance Window for Low Energy Ions and Neutral Particles
Princeton Scientific Instruments, Inc. 7 Deer Park Drive Monmouth Junction, NJ 08852-1921	Second Harmonic Imaging Interferometry for Magnetic Fusion Devices

TOPIC: TECHNOLOGY AND INSTRUMENTATION FOR HEAVY ION FUSION ACCELERATORS

Alameda Applied Sciences Corporation 1555 Doolittle Drive Suite 100 San Leandro, CA 94577	High Current Ion Source for Heavy Ion Fusion

First Point Scientific, Inc. 5300 Derry Avenue Suite J Agoura Hills, CA 91301-4501	The Miniature Inductive Adder, an All Solid-State Pulsed Power Modulator for Heavy Ion Fusion

TOPIC: HIGH ENERGY PHYSICS DATA ACQUISITION AND PROCESSING

Conductus, Inc. 969 West Maude Avenue Sunnyvale, CA 94086-2802	High Temperature Superconductor Pulse Amplifiers for High-Speed Low-Noise Applications

TOPIC: HIGH ENERGY PHYSICS DETECTORS

Biogeneral, Inc. 11055 Flintkote Avenue San Diego, CA 92121-1220	High Numerical Aperture Scintillating Fibers
Energy Science Laboratories, Inc. 6888 Nancy Ridge Drive San Diego, CA 92121-2232	Carbon Thermostructure for Silicon-Based Particle Detectors
Epikon, Inc. 5069 Corbin Drive Suite C Bedford Heights, OH 44128	Development of Scintillators and Waveshifters for Detection of Ionizing Radiation
NanoSystems Inc. 83 Prokop Road Oxford, CT 06478-1108	Light Amplifier
Radiation Monitoring Devices, Inc. 44 Hunt Street Watertown, MA 02172-4699	High Performance Optical Detectors for Calorimetry

TOPIC: TECHNOLOGY AND INSRUMENTATION FOR HIGH ENERGY ACCELERATORS

Adelphi Technology, Inc. 2181 Park Boulevard Palo Alto, CA 94306-1543	A Compact, Inexpensive Electron Source
American Magnetics, Inc. P.O. Box 2509 Oak Ridge, TN 37831-2509	Design, Development, and Fabrication of Hybrid High Temperature Superconducting Current Leads

Duly Research, Inc. 1912 MacArthur Street Rancho Palos Verdes, CA 90275-1111	Ultra-High Frequency Planar Accelerating Structure for Future Linear Colliders and Compact Accelerators
Duly Research, Inc. 1912 MacArthur Street Rancho Palos Verdes, CA 90275-1111	A Plane Wave Transformer Photoelectron Accelerator
FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236	A Micro-Pulse Electron Injector
FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236	Accelerating Cavities for a Relativistic Klystron Two-Beam Accelerator
FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236	Bending System for Recirculating Accelerators with Space-Charged Dominated Beams
Fusion and Accelerator Research 3146 Bunche Avenue San Diego, CA 92122-2247	Design of Novel Induction Accelerator Gaps
G. H. Gillespie Associates, Inc. P.O. Box 2961 Del Mar, CA 92014-5961	Graphically Driven Optimization Tool for Particle Optics Simulation Programs
JP Accelerator Works 2245 47th Street Los Alamos, NM 87544-1604	500 Megawatt Axial Free Electron Laser Microwave Power Source
MDS Company 1955 Mountain Boulevard Suite 101 Oakland, CA 94611-2812	Development of a 300 Megawatt S-Band Relativistic Klystron Amplifier
Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706-9237	An Innovative Approach to Synthesis to Porous Intermetallic Matrix Composites for Regenerative Cooling Below 20 Degrees Kelvin

Mission Research Corporation 735 State Street P.O. Drawer 719 Santa Barbara, CA 93101-3351	Triaxial Klystron Amplifier for Advanced Radio Frequency Accelerators
Northwest Effect 5165 Cecilia Street, SE Salem, OR 97306-1724	Improved Critical Current Density at High Fields and Reduced Processing Costs for Ductile Niobium Titanium Alloys
Omega-P, Inc. 202008 Yale Station New Haven, CT 06520-2008	Efficient Centimeter-Wavelength Gyroharmonic Converter -- Radio Frequency Source for a Future Collider
Omega-P, Inc. 202008 Yale Station New Haven, CT 06520-2008	A Microwave Active Bragg Compressor
Physical Sciences, Inc. 20 New England Business Center Andover, MA 01810-1022	Design of an Axially-Modulated, Cusp Injected, Large Orbit Gyrotron for Linear Collider Applications
Positive Light, Inc. 103 Cooper Court Los Gatos, CA 95030-3321	Multi-Terrawatt Laser for Electron Beam Accelerator Applications
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545-3301	Development of Artificial Pinning Center Niobium-Titanium-Tantalum Conductor for High Field Applications
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545-3301	Development of a New High-Field Niobium Titanium Superconductor with Mechanically Introduced Tantalum Inclusions
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545-3301	Niobium Titanium Ternary and Quarternary Alloys for High Field (>8 Tesla) Applications
Tech-X Corporation 4588 Pussywillow Court Boulder, CO 80301-5830	Object Oriented Accelerator Modeling Code With a Graphical User Interface

TOPIC: NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

ALEM Associates 303A Commonwealth Avenue Boston, MA 02115-2096	Improved Ultrafast Scintillators for Nuclear Physics
Applied Physics Technologies 25 East Loop Road Stony Brook, NY 11790-3350	A Lanthanium Fluoride:Neoymium Photosensitive Wire Chamber for Gamma-Ray Imaging
Conductus, Inc. 969 West Maude Avenue Sunnyvale, CA 94086-2802	An Oversampling Delta-Modulator for Digitizing Amplitude of Ultra-Short Pulses Based on High Temperature Superconductor
Innova Laboratories, Inc. 11199 Sorrento Valley Road Suite L San Diego, CA 92121-1334	Large Area Pixelated and Tiled X-Ray and Gamma-Ray Detector
Intraspec, Inc. P.O. Box 4579 Oak Ridge, TN 37831-4579	Improved Cost and Radiation Hardness for Silicon Detectors
Scientific Digital Visions, Inc. 4 North Second Street Suite 225 San Jose, CA 95113-1308	Advanced Methods for Accessing and Disseminating Nuclear Data
Spire Corporation One Patriots Park Bedford, MA 01730-2396	Coplanar Cadmium Zinc Telluride Positive-Insulator-Negative, Gamma-Ray Detectors for Nuclear Spectroscopy
W. Peter Trower, Inc. 1105 Highland Circle Blacksburg, VA 24060-5618	Large Room Temperature Cadmium-Zinc Telluride Detectors

TOPIC: NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

Amparo Corporation P.O. Box 2687 Santa Fe, NM 87504-2687	High Power Target Design for a Next Generation Radioactive Beam Isotope Separator On Line-Type Facility
Beam Diagnostics Lab, Inc. 5255 15th Avenue, NE Suite 303 Seattle, WA 98105-3449	Optical Delay Line Loop Sampler for Multichannel Very Short Single Shot Transient Signals

Composite Technology Development, Inc. 2400 Central Avenue, Suite H Boulder, CO 80301-2843	Low Loss Silicon Nitride Technology for High Power Radiofrequency Transmission Windows

TOPIC: EDUCATIONAL INSTRUCTIONAL MODULES

Mission Research Corporation 735 State Street P.O. Drawer 719 Santa Barbara, CA 93101-3351	Educational Instructional Modules 'Apollo 2000'
Optimal Analysis Company, Inc. 313 First Street Hoboken, NJ 07030-2440	The Real Stuff II

TOPIC: TECHNOLOGY FOR SPACE NUCLEAR PROPULSION AND POWER

Advanced Modular Power Systems, Inc. 4667 Freedom Drive Ann Arbor, MI 48108-9784	Directed Reflectivity, Long Life Alkali Metal Thermal Electric Converter Condenser

TOPIC: TESTING, INSPECTION, AND CHARACTERIZATION OF MATERIALS AND COMPONENTS IN COMMERCIAL LIGHT WATER REACTORS

Advanced Technology Corporation 115 Clemson Drive Oak Ridge, TN 37830-7665	In-Situ Nondestructive Measurements of Key Mechanical Properties of Reactor Pressure Vessels Using Innovative Stress-Strain Microprobe Technology
Pacific-Sierra Research Corporation 1400 Key Boulevard Suite 700 Arlington, VA 22209	Oxidation Induction Time Technology for Electric Cable Condition Monitoring and Life-Assessment

DEPARTMENT OF ENERGY

STTR

1994

PHASE I

AWARDS

SELECTION STATEMENT FOR PHASE I AWARDEES UNDER THE SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM FOR FISCAL YEAR 1994 (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0605)

U. S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585
SEPTEMBER 2, 1994

SELECTION OF GRANT APPLICATIONS FOR NEGOTIATION OF SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM PROJECTS FOR FISCAL YEAR 1994 UNDER PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0605

This is the first year of the STTR program, a three-year pilot program created by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564). This program is similar in many respects to the Small Business Innovation Research (SBIR) program for which the DOE has held competitions for the last twelve consecutive years. The major difference is that, in STTR, P.L. 102-564 requires the small business applicant to collaborate with a non-profit research institution that would be a subcontractor on any funded application. The small business must perform at least 40% of the work on the project, and the research institution must perform at least 30%.

An STTR Application Score Verification Panel (ASVP) was appointed to evaluate Phase I applications for the STTR program. As a former chairman of the SBIR ASVP, I am familiar with the Panel's evaluation procedures and its methodology. I have received reports from the Technical Topic Managers (TTMs) who were responsible for the review of the 12 technical topic areas listed in the solicitation. I believe that the Panel and the TTMs have proceeded in accordance with applicable laws and regulations, that the evaluation has been thorough and equitable, and that the information presented forms a sound basis for selection. Consequently, I have selected 21 applications received under this solicitation for negotiation for award of Phase I Fiscal Year (FY) 1994 STTR grants. This statement describes the procurement and sets forth the basis for my selection decision.

Procurement Description

Public Law 102-564 requires that each Federal agency with an extramural research or research and development budget exceeding $1 billion establish an STTR pilot program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector and in non-profit research institutions. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies are as follows:

Fiscal Year	STTR Set Aside (%))
1994	0.05
1995	0.10
1996	0.15

Public Law 102-564 also prescribes that the STTR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the STTR program. This phase will have a period of performance which is typically nine months in duration. Awards will be up to $100,000 for Phase I projects.

Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $500,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-STTR funded Federal contracts for products or services intended for use by the U.S. Government.

Applications Received

Outreach efforts for the DOE STTR program were considerable. DOE mailed out approximately 30,000 1994 solicitations to those on an extensive mailing list used for the SBIR program, and to other individuals requesting copies. In addition, the STTR solicitation was advertised in the Commerce Business Daily on December 27, 1993. It also received coverage in trade journals and newsletters and in various Small Business Administration information releases and conferences.

A total of 487 applications were received in response to the solicitation. The solicitation listed 12 technical topic areas to which applicants could respond. The list of technical topic areas and the number of applications received in each area are as follows:

1.	Advanced Manufacturing for Nuclear Weapons Systems	50
2.	Flat Panel Display Technology and Manufacturing Processes	61
3.	Engineered Materials for Nuclear Weapons Systems	33
4.	Nickel Metal Decontamination Technology	9
5.	Environmentally Benign Physical and Chemical Processes	81
6.	Biotechnology: Resources and Applications	49
7.	Specialized Components for and Research on High Energy Electron Accelerators	29
8.	Technologies in Support of Nuclear Physics Research	33
9.	Fusion Technology	36
10.	Nuclear Fuel and Energy Conversion Technology	17
11.	Control Software for Fossil Energy Applications	72
12	New Environmentally Benign Industrial Solvents	12

Five applications received could not be assigned to a specific topic or subtopic.

Of the 487 applications received, 35 were eliminated for administrative reasons; DOE staff determined that these applications failed to meet one or more material requirements of the solicitation. One application was withdrawn by the proposing firms.

The remaining 451 were judged on a competitive basis in a two-step process. The first step of that process was a screening by the TTMs and DOE staff knowledgeable in the topic area to determine the relevance of each application to a chosen topic by the extent to which it responded to a specific topic area. Then it was determined whether each application was for research or research and development, whether it provided sufficient information for a full evaluation, whether it was duplicative of other ongoing or previous efforts, and finally, whether it was of sufficiently high quality for award. One hundred ninety-four applications were eliminated after the first step technical review. The 257 applications found to be relevant were evaluated in the second step according to criteria listed in the solicitation and set out below.

Selection Criteria and Rationale

Phase I awards were made on scientific and technical merit based upon the criteria listed below. Approximately equal consideration was given to each of the following criteria:

(1) The scientific/technical quality of the research in the Phase I grant application.

(2) The degree of innovation demonstrated by the grant application.

(3) The qualifications of the Principal Investigator, other key staff, and consultants, if any, and the level of adequacy of available or obtainable instrumentation and facilities.

(4) The anticipated benefits, technical and/or economic, of the proposed research (Phase I and Phase II), if successful, with special emphasis on the likelihood that the project will attract further funding for product or process development after the STTR support expires.

(5) The soundness and level of adequacy of the Phase I proposed work plan to show progress toward proving the feasibility of the concept.

For each of the 12 technical topic areas listed in the solicitation, there was a TTM who, along with reviewers both internal to DOE and external - selected from among DOE Laboratory personnel, university researchers, and private industry personnel - evaluated and scored applications against the assigned criteria. Reviewers were selected in accordance with conflict of interest policies which have been used for the SBIR program. In addition, for STTR, no person affiliated with a research institution was allowed to review a grant application that named that research institution as a participant.

An Application Score Verification Panel (ASVP) consisting of technical staff from both within and without DOE was established to ensure relative uniformity of scoring across the 12 topic areas and to ensure that scores were based on meaningful technical reviews. The ASVP was also chartered to ensure that there was consistency of scoring within topics.

I have examined the evaluation documentation presented by the TTMs. I have also carefully reviewed the recommendations of the ASVP and have agreed that the evaluations of the TTMs and the recommendations of the ASVP provided valid bases upon which to make a selection. Therefore, based on those recommendations, and in consideration of applications whose funding would contribute to a programmatically-balanced set of STTR-supported projects, I have selected 21 applications for negotiations. Included in these are all applications which received the highest possible technical rating. The remainder was selected from among applications that were rated one point below the highest possible technical rating, on the basis of program balance. It is my view that these applications represent outstanding technical quality and are worthy of selection for this program.

Selected Applications

Appendix A is a listing of the applications selected for negotiations leading to award. The STTR program is a three-year pilot program, and continued participation in later solicitations is strongly encouraged.

Samuel J Barish

Samuel J. Barish
STTR Program Manager

Date: 9/2/94

Attachment:
List of Grant Applications
Recommended for Awards

APPENDIX A
DEPARTMENT OF ENERGY
SMALL BUSINESS TECHNOLOGY TRANSFER
GRANT APPLICATIONS SELECTED FOR FY 1994 AWARDS

Small Business	Research Institution
TOPIC: ADVANCED MANUFACTURING FOR NUCLEAR WEAPONS SYSTEMS	
Intelligent Systems Technology, Inc. 3100 Dannyhill Drive Los Angeles, CA 90064	Los Alamos National Laboratory
Project: Simulation-Based Analysis and Design of Agile Manufacturing Systems	
TOPIC: FLAT PANEL DISPLAY TECHNOLOGY AND MANUFACTURING PROCESSES	
Planar Systems, Inc. 1400 Northwest Compton Drive Beaverton, OR 97006	Los Alamos National Laboratory
Project: Feasibility of Nitride Phosphors for Thin Film Electroluminescent Displays	
TOPIC: ENGINEERED MATERIALS FOR NUCLEAR WEAPONS SYSTEMS	
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	Sandia National Laboratory
Project: Preparation of Monolithic Porous Carbon Materials Using Controlled Functionalization of Fullerenes	
TOPIC: ENVIRONMENTALLY BENIGN PHYSICAL AND CHEMICAL PROCESSES	
Kroftt-Brakston International, Inc. 5836 Sunrise Avenue Clarendon Hills, IL 60514	Argonne National Laboratory
Project: A Continuous Chemical Manufacturing Process for Direct Production of Titanium Powder with a Reagent Recycle	

Small Business	Research Institution

TOPIC: BIOTECHNOLOGY: RESOURCES AND APPLICATIONS

Electrokinetics, Inc. South Stadium Drive LBTC, Suite 155 Baton Rouge, LA 70803-6100	Argonne National Laboratory

Project: In-situ Bioremediation by Electrokinetic Injection

Immersion Human Interface Corporation 2483 Old Middlefield Way Suite 160 Mountain View, CA 94043	Ohio Supercomputer Center

Project: A Haptic Interface for Virtual Exploration of Computational Data

Newton Scientific, Inc. 7 Redcoach Lane Winchester, MA 01890	Washington University, St. Louis, Missouri

Project: Development of Kits for the Efficient and Automated Synthesis of Copper-64 Radiopharmaceuticals

TOPIC: SPECIALIZED COMPONENTS FOR AND RESEARCH ON HIGH ENERGY ELECTRON ACCELERATORS

Duly Research, Inc. 1912 MacArthur Street Rancho Palos Verdes, CA 90732	Stanford Linear Accelerator Center University of Illinois at Chicago

Project: Design and Microfabrication of Asymmetric Planar Accelerating Structures

FM Technologies, Inc. 10529-B Braddock Road Fairfax, VA 22032	Los Alamos National Laboratory

Project: A Robust High-Current-Density Electron Gun

Small Business	Research Institution
JP Accelerator Works 2245 47th Street Los Alamos, NM 87544	Los Alamos National Laboratory

Project: A 500 Megawatt Microwave Free Electron Laser

North Star Research Corporation 9931 Lomas, Northeast Suite A Albuquerque, NM 87112	Stanford Linear Accelerator Center

Project: An Efficient, Low Cost Power Modulator System for High Power Klystrons

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TOPIC: TECHNOLOGIES IN SUPPORT OF NUCLEAR PHYSICS RESEARCH

ARACOR 425 Lakeside Drive Sunnyvale, CA 94086	Lawrence Berkeley Laboratory

Project: An Integrated X-ray Sensor

LeCroy Corporation/Jorway Corporation 700 Chestnut Ridge Road Chestnut Ridge, NY 10977-6499	Yale University

Project: An Extension of the CAMAC Standard for Increased Data Transfer Rates

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TOPIC: FUSION TECHNOLOGY

DELTA M Corporation 525 Warehouse Road Oak Ridge, TN 37830	Oak Ridge National Laboratory

Project: Improved Mineral Insulated Cables for Fusion Reactor Diagnostics

Small Business	Research Institution
Lawrence Semiconductor Research Laboratory, Inc. 2300 West Huntington Drive Tempe, AZ 85282	Lawrence Livermore National Laboratory

Project: A Microcalorimeter for High Resolution, Broad Band X-Ray Spectroscopy of Tokamak Plasmas

Materials and Electrochemical Research Corporation 7960 South Kolb Road Tucson, AZ 85706	University of Illinois at Urbana/Champaign

Project: Development of a Commercial High-Velocity Hydrogen Pellet Injector Using Railgun Technology

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TOPIC: NUCLEAR FUEL AND ENERGY CONVERSION TECHNOLOGY

JX Crystals, Inc. 1085 12th Avenue Northwest Suite D8 Issaquah, WA 98027	Jet Propulsion Laboratory

Project: A High Efficiency Radioisotope Thermophotovoltaic Generator Design

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TOPIC: CONTROL SOFTWARE FOR FOSSIL ENERGY APPLICATIONS

ERC, Inc. 205 Research Park Drive P.O. Box 417 Tullahoma, TN 37388	University of Tennessee Space Institute

Project: Boiler Optimization Using Advanced Learning Techniques

PSI PowerServe 20 New England Business Center Andover, MA 01810-1077	Lehigh University

Project: Nitrogen Oxide Compliance and Adjustment of Coal Burners Based on Flame Frequency Spectra Analysis

Small Business	Research Institution
TomoSeis, Inc. 1650 West Sam Houston Parkway North Houston, TX 77043	Lawrence Livermore National Laboratory

Project: Constraining Seismic Traveltime Tomography to Produce
Optimal Layered Earth Models

Small Business	Research Institution
TomoSeis, Inc. 1650 West Sam Houston Parkway North Houston, TX 77043	University of California at Berkeley

Project: Crosswell Reflection Imaging with Amplitude Corrections

DOE/ER-0623

STTR

Small
Business
Technology
Transfer

Abstracts of Phase I Awards

1994

U.S. Department of Energy
Office of Energy Research
STTR Program Manager
Washington, D.C. 20585

DOE/ER-0623

STTR

Small
Business
Technology
Transfer

Abstracts of Phase I Awards

1994

U.S. Department of Energy
Office of Energy Research
STTR Program Manager
Washington, D.C. 20585

PREFACE

This booklet presents technical abstracts of Phase I awards made in Fiscal Year (FY) 1994 under the DOE Small Business Technology Transfer (STTR) program. STTR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. Brief comments on the potential applications, as described by the awardee, are given after each abstract. Individuals and organizations, including venture capital and larger industrial firms, with an interest in the research described in any of the abstracts are encouraged to contact the appropriate small business directly.

The Federal STTR Program

The STTR program, now completing its first year, was established as a three-year pilot program in compliance with the Small Business Research and Development Enhancement Act of 1992, Public Law 102-564. Five Federal agencies have STTR programs - those with extramural research and development (R&D) budgets over $1 billion. The agencies were required to set aside 0.05% of those budgets in FY 1994 to fund STTR projects. (This amounted to about $2 million for the Department of Energy.) The set-aside will increase to 0.10% in FY 1995 and 0.15% in FY 1996. Each agency solicits grant applications from small science- and technology-based U.S. firms (with 500 employees or less) in collaboration with a non-profit research institution (e.g. National laboratories and universities). Awards are made competitively to the small business with the collaborating research institution serving as a subcontractor. STTR supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about nine months, and awards are limited to $100,000. Phase II is the principal research or R&D effort, and only Phase I awardees can compete for Phase II awards of up to $500,000 in FY 1995 for work to be performed in a period of up to two years. In Phase III, commercial applications of the research or R&D is pursued using non-Federal funding or, alternatively, it may involve follow-on non-STTR Federal contracts for products or services desired by the Government.

The DOE STTR Program

DOE's FY 1994 annual solicitation contained 12 technical topics in basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, defense programs, energy efficiency and renewable energy, environmental management, fossil energy, and nuclear energy.

The 21 Phase I projects described here were selected in a highly competitive process from a total of 487 grant applications received in response to the 1994 DOE annual STTR solicitation. The selections for awards were made on scientific and technical merit, as judged against the specific criteria listed in the solicitation. Conclusions were reached on the basis of reviews performed by personnel in DOE laboratories, universities, private industry, and government. Reviewers were selected in accordance with conflict of interest policies which, for example, did not permit a person affiliated with a research institution to review a grant application that named that research institution as a participant. It is expected that between one-third and one-half of the Phase I projects will be continued into Phase II.

The DOE STTR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. This feature, which allows continuity of funding, has been successfully provided to awardees in the DOE Small Business Innovation Research (SBIR) program for the past eleven years. Since 1984, about 40% of the SBIR Phase II awardees have had continuous funding between Phases I and II.

DOE also hopes to provide STTR Phase II awardees with the opportunity to participate in its Commercialization Assistance Program (CAP) which has been offered to SBIR Phase II awardees for the past five years. Since many small companies lack the business skills necessary for rapid commercialization of their technologies, the CAP provides successful Phase II awardees with individual assistance in developing a business plan and preparing sound and concise visual materials to describe business opportunities. The project culminates in presentations to potential sponsors, including representatives from large corporations and venture capital firms. As a result of participation in the 1991 project, SBIR companies have already received more than $14 million for commercialization of their SBIR research with a projected royalty stream from option agreements of an additional $24 million over the next five years. About 43% of the firms that completed the project have received further funding for their work.

The STTR program enables DOE to obtain effective, innovative solutions to important problems through the collaboration of technology-based small businesses with non-profit research institutions. We expect that the private sector participants will have the commercial incentive to pursue the resulting technology and bring it to the marketplace.

Samuel J. Barish
STTR Program Manager
U.S. Department of Energy
Washington, DC 20585

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ADVANCED MANUFACTURING FOR NUCLEAR WEAPONS SYSTEMS

1

Small Business
Intelligent Systems Technology, Inc.
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Los Angeles, CA 90064
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Ms. Carla C. Madni, Business Official
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Research Institution
Los Alamos National Laboratory
Advanced Engineering Technology
P.O. Box 1663, MS J576
Los Alamos, NM 87545

Simulation-Based Analysis and Design of Agile Manufacturing Systems

DOE Grant No. DE-FG03-94ER86006
Amount: $99,994

Success in manufacturing today depends on the manufacturer's ability to deliver top quality custom products in varying quantities rapidly and affordably. This capability is referred to as agile manufacturing. Equipped with such a capability, manufacturers will be able to reconfigure their lines rapidly in response to changing market opportunities and fluctuating demands on a routine basis. This project should create an interactive computer program that will allow users to model, simulate, and evaluate various agile manufacturing configurations and improvement options before committing to equipment purchase. Phase I will specify the system concept and implementation plan for the computer program. The computer program will consist of a commercially available manufacturing simulation package, an analysis module, and a graphical output display module, as well as manufacturing application-specific data bases developed under the planned project.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project should result in a simulation-based toolkit for the design and evaluation of manufacturing improvements before committing to manufacturing capability upgrade or new equipment purchase. Potential commercial applications include computer integrated manufacturing (CIM), business process re-engineering (BPR), and integrated product-process development (IPPD). Vertical markets include consumer electronics, health care delivery systems, and semiconductor and electro-mechanical manufacturing.

FLAT PANEL DISPLAY TECHNOLOGY AND MANUFACTURING PROCESSES

2

Small Business
Planar Systems, Inc.
1400 Northwest Compton Drive
Beaverton, OR 97006
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Dr. Christopher N. King, Business Official
(503) 690-1100

Research Institution
Los Alamos National Laboratory
Chemical Science and Technology Division
P.O. Box 1663, CST-3
Los Alamos, NM 87545

Feasibility of Nitride Phosphors for Thin Film Electroluminescent Displays

DOE Grant No. DE-FG03-94ER86011
Amount: $100,000

This project will investigate a new class of host materials, the Group III metal nitrides, for application as the light emitting layer in thin film electroluminescent flat panel displays. The project is aimed at improving the luminance of the blue emission in full color electroluminescent displays. Insulating gallium nitride, aluminum gallium nitrides, and aluminum indium nitride films will be deposited by metalorganic chemical vapor deposition. The deposition process will employ novel Group III precursor compounds to grow the nitride films at temperatures compatible with commercial display glass substrates. Dopant ions will be introduced into the nitride layers by ion implantation and evaluated as centers for blue electroluminescence. Rapid thermal annealing will be employed to redistribute the dopant ions in the nitride layer. The chemical composition, microstructure, and dopant profiles of the nitride layers will be characterized using thin film analytical techniques. Thin film electroluminescent devices employing the doped nitride layers will be prepared and characterized for spectral response, luminance, and efficiency.

Anticipated Results/Potential Commercial Applications as described by the awardee: It is anticipated that this project will result in new blue-emitting electroluminescent phosphor films prepared at temperatures less than 600°C which could lead to the U.S. manufacture of commercial full-color flat panel displays.

ENGINEERED MATERIALS FOR NUCLEAR WEAPONS SYSTEMS

3

Small Business
TDA Research, Inc.
12345 West 52nd Avenue
Wheat Ridge, CO 80033
Dr. William L. Bell, Principal Investigator
Mr. Michael E. Karpuk, Business Official
(303) 940-2301

Research Institution
Sandia National Laboratory
Chemistry of Organic Materials
Department 1811, MS 0368
Albuquerque, NM 87185-0368

Preparation of Monolithic Porous Carbon Materials Using Controlled Functionalization of Fullerenes

DOE Grant No. DE-FG02-94ER86017
Amount: $100,000

Porous carbons have commercial uses as electrode materials, sorbents, catalyst supports, and structural materials, and are also important in the Defense Programs. Fullerene carbon, a recently discovered soluble, molecular form of carbon, now offers an opportunity to prepare a new family of monolithic porous carbon materials. Engineered carbon materials have been prepared by first forming a polymeric solid, followed by extraction and pyrolysis to produce porous carbons with control over the pore size distribution. Incorporation of fullerenes would increase the carbon content of the polymer and the yield of porous carbon after pyrolysis. This change should improve retention of the original polymer structure and allow near net-shape processing. Because the chemical and electrochemical properties of the fullerenes will be incorporated into the porous carbons, these materials should have unique and potentially very useful properties. The most desirable fullerene building block would contain two suitable functional groups on opposite sides of the fullerene spheroid. This arrangement would allow optimum connectivity, while leaving most of the fullerene surface free. Such difunctional building blocks are extensively used in polymer chemistry to form rigid, highly crosslinked materials. Unfortunately, no such fullerene compounds are currently available. A synthetic route to such difunctional fullerenes has been identified. Phase I will first establish the synthetic chemistry, and then use the new difunctional fullerenes, with methods that have been previously demonstrated with multiply substituted fullerenes, to produce and characterize monolithic porous carbons. Phase II will systematically explore the properties and potential applications of the new materials, leading toward Phase III commercialization.

Anticipated Results/Potential Commercial Applications as described by the awardee: A successful project (Phases I, II,and III) should lead to improved fullerene-based engineered porous carbons, which have commercial application as electrode materials, sorbents, catalysts, and catalyst supports, and structural materials. Such materials could also be beneficial to the Defense Programs.

ENVIRONMENTALLY BENIGN PHYSICAL AND CHEMICAL PROCESSES

4

Small Business
Kroftt-Brakston International, Inc.
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Clarendon Hills, IL 60514
Mr. Richard P. Anderson, Principal Investigator
Dr. Donn R. Armstrong, Business Official
(708) 655-3065

Research Institution
Argonne National Laboratory
Energy Technology Division
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Argonne, IL 60439

A Continuous Chemical Manufacturing Process for Direct Production of Titanium Powder with a Reagent Recycle

DOE Grant No. DE-FG02-94ER86013
Amount: $97,725

The objective of this project is to demonstrate the feasibility of an innovative, breakthrough chemical manufacturing process for the economical manufacture of titanium. The process to be demonstrated is a one-stage, continuous process that produces pure titanium metal through the reduction reaction between titanium tetrachloride and sodium. There is strong demand for the development of a process that enables continuous economical production of titanium powder suitable for use without additional processing for application to power metallurgy or vacuum-arc melting to ingot form. The planned chemical manufacturing process offers four clear and distinct advantages over currently practiced titanium production technology, that is, the Kroll process and the Hunter process. These advantages are: (1) greatly reduced environmental impact through recycle of the reducing agent, (2) continuous process technology, providing a significant competitive commercial advantage over current batch technology, (3) utilization of the reaction heat from the highly exothermic reduction of titanium tetrachloride as an integral part of the process, greatly reducing energy consumption required for titanium manufacture, and (4) direct production of the product titanium metal in a powder form, eliminating the manpower intensive and hazardous processing required to convert titanium sponge produced via the Hunter or Kroll processes into a usable form.

Anticipated Results/Potential Commercial Applications as described by the awardee: Development and implementation of this chemical manufacturing process should meet critical industry needs and substantially reduce the environmental impact of titanium production. Development of a more commercially competitive process for producing titanium could (1) enable large-scale use in automotive, manufacturing, chemical, construction, and other industries, (2) reduce the U.S. mineral supply vulnerability by utilizing plentiful domestic titanium sources in place of imported substances such as chromium, cobalt, and nickel, and (3) provide a major economic benefit to the United States, improve the U.S. balance of payments, and contribute to enhanced U.S. industrial competitiveness.

BIOTECHNOLOGY: RESOURCES AND APPLICATIONS

5

Small Business
Electrokinetics, Inc.
South Stadium Drive
LBTC; Suite 155
Baton Rouge, LA 70803-6100
Dr. Robert E. Marks, Principal Investigator
Dr. Yalcin B. Acar, Business Official
(504) 388-3992

Research Institution
Argonne National Laboratory
Energy Systems Division
9700 South Cass Avenue
Argonne, IL 60439

In-situ Bioremediation by Electrokinetic Injection

DOE Grant No. DE-FG05-94ER86005
Amount: $97,831

In situ bioremediations are impeded by problems of transporting microbial populations and nutrients into subsurface soils. Microbial transport is most hindered in clay soils. This may result in injection of nutrients and microbial populations. However, nutrients may not be present in sufficient quantities to initiate the biodegradation process in adjacent organically polluted contaminated soil. This project will use patented electrokinetic subsurface soils technology coupled with "In-Situ" bioremediation (patent pending) to accomplish the following three proof-of-concept bench scale tasks: (1) distribution of electrically charged nutrients (ECNs) uniformly through subsurface soils; (2) demonstration that ECNs can be directed to a specific nutrient deficient subsurface contaminated soil which contains organic contaminants of concern including polyaromatic hydrocarbons (PAHs) and chlorinated organics (e.g., trichlorethylene, carbon tetrachloride, etc.); and (3) delivery of acclimated microorganisms to a soil segment containing a subsurface hydrocarbon food source. Nitrate or ammonium ions will be considered as possible ECN candidates. A field demonstration will be the central focus of Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: The coupled technologies of "In-Situ" electrokinetic soil processing and bioremediation are predicted to have advantages over dig/haul and treat, encapsulation, solidification, thermal destruction, soil washing, etc. which result in soil destruction, disturbed soils, retained subsurface wastes, and proliferation of landfills. The bioelectrokinetic remediation process is predicted to remove organic pollutants more uniformly and efficiently from contaminated soils than comparable in-situ bioremediation processes such as soil venting or bio-venting.

6

Small Business
Immersion Human Interface Corporation
2483 Old Middlefield Way
Suite 160
Mountain View, CA 94043
Dr. Louis B. Rosenberg, Principal Investigator
Mr. Timothy A. Lacey, Business Official
(415) 960-6882

Research Institution
Ohio Supercomputer Center
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Columbus, OH 43212

A Haptic Interface for Virtual Exploration of Computational Data

DOE Grant No. DE-FG03-94ER86008
Amount: $94,910

Virtual exploration of complex models has become accessible to a wide user population as a result of recent advances in graphic display technologies. Unfortunately, few human interface tools exist which allow users to interact naturally with these realistic graphical environments. To enhance the exploration and interpretation of three-dimensional data, a user interface mechanism will be developed which allows natural manual interaction with three-dimensional environments by providing realistic force feedback to the user. A haptic display methodology will allow for high fidelity force feedback at reduced cost with a mechanism which is inherently safe for the user. The combination of high fidelity, low cost, and inherent safety would bring force reflection technology out of the laboratory and onto the desks of engineers, scientists, and medical professionals who could use haptic feedback when exploring computer models. The overall project objective is to develop a full 6 degree-of-freedom haptic interface for virtual environments. Phase I will focus on producing a 3 degree-of-freedom haptic interface hardware device and incorporating it into a real world application. A virtual simulation of endoscopic sinus surgery will be produced. This is a medical procedure requiring dexterous manual activity in three degrees of freedom. A CT-scan and MR-scan volumetric data set will be used to generate virtual models of the sinus cavity with both visual and haptic representations. The virtual model will be used to train medical practitioners. Development and testing of this haptic interface should provide valuable insights into the design requirements for haptic display and should provide design specifications for the full 6 degree-of-freedom interface to be developed in Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: A 6 degree-of-freedom haptic display could have immediate commercial applications in the medical simulation and scientific visualization fields. The technology is also applicable to every form of computer interface, including computer-aided design packages, scientific modeling, entertainment, and educational tutorials.

7

Small Business
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Winchester, MA 01890
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(617) 729-8553

Research Institution
Washington University
Division of Radiation Sciences
724 South Euclid
St. Louis, MO 63110
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(314) 362-8435

Development of Kits for the Efficient and Automated Synthesis of Copper-64 Radiopharmaceuticals

DOE Grant No. DE-FG02-94ER86015
Amount: $97,750

Positron emission tomography (PET) generally utilizes radionuclides with half-lives of two hours or shorter. This project will develop simple, automated procedures for the production of a variety of novel radiopharmaceuticals labeled with the medium half-lived radionuclide copper-64. Copper-64 has a half-life of 12.8 hours which will allow the transportation of PET radiopharmaceuticals to imaging centers without a cyclotron. Copper-64 will be produced by the ^{64}Ni(p,n)^{64}Cu nuclear reaction which will be adapted to small and medium energy biomedical cyclotrons. Three series of compounds will be radiolabeled. These series of compounds are: (1) Lypophilic copper chelate which has been shown to have potential for the measurement of blood flow in the brain, heart, kidney, and tumors; (2) Monoclonal antibodies and antibody fragments which have potential for both diagnosis and therapy; and (3) Small peptides, such as octreotide, which have potential for both diagnosis and therapy. In Phase I labeling yields of the three types of compounds will be maximized, and automated synthetic modules will be designed.

Anticipated Results / Potential Commercial Applications as described by the awardee: It is anticipated that this project will develop automated procedures for the production of a new series of positron emitting radiopharmaceuticals. The commercial partner should be able to market kits and/or production modules for the preparation of three important groups of radiopharmaceuticals. These modules should not only be able to be used to label the specific compounds being investigated but should be easily adapted to others similar in chemical type.

SPECIALIZED COMPONENTS FOR AND RESEARCH ON HIGH ENERGY ELECTRON ACCELERATORS

8

Small Business
Duly Research, Inc.
1912 MacArthur Street
Rancho Palos Verdes, CA 90732
Dr. David U.L. Yu, Principal Investigator
and Business Official
(310) 548-7123

Research Institution
Stanford Linear Accelerator Center
Accelerator Theory and Special Projects
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Stanford, CA 94309

Design and Microfabrication of Asymmetric Planar Accelerating Structures

DOE Grant No. DE-FG03-94ER86007
Amount: $97,831

An asymmetric planar structure, different from the traditional cylindrically symmetric structure, is planned to accelerate a flat rectangular beam in a linear electron accelerator. The structure can be mass produced with modern microfabrication techniques using deep etch x-ray lithography. Phase I will study the physics issues and fabrication techniques of the planar accelerating structure (PAS), and the feasibility of their application to future linear colliders and compact commercial linear accelerators operated at high frequencies. The PAS can be designed with a nearly constant axial electric field in the central region of the cavity through which the beam passes. Such a structure would reduce wakefields, and accommodate a high-current beam while maintaining a low current density. The PAS can also be used to accelerate electrons emitted by an asymmetric photoinjection gun, possibly eliminating the need for an expensive damping ring to control emittances. Asymmetric radio frequency quadrupole beam focusing in a PAS-based linac is also possible. Precision microfabrication techniques are especially suitable for repeatable production of small, high-aspect-ratio structures with tight tolerances. These techniques would replace tedious machining and brazing manufacturing processes for very small and intricate structure, and could substantially reduce the manufacturing cost.

Anticipated Results / Potential Commercial Applications as described by the awardee: The asymmetric planar accelerating structure is a revolutionary design which should be applicable to a new generation of commercial linear accelerators and linear colliders. Microfabrication of a PAS using lithography techniques should save production cost and increase precision. Microfabricated, PAS-based linacs can be used as compact medical and industrial accelerators, and as compact injectors to microfabricated free electron lasers to produce coherent, tunable radiations.

9

Small Business
FM Technologies, Inc.
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Fairfax, VA 22032
Dr. Frederick M. Mako, Principal Investigator
and Business Official
(703) 425-5111

Research Institution
Los Alamos National Laboratory
Applied Theoretical Physics Division
P.O. Box 1663
Los Alamos, NM 87545

A Robust High-Current-Density Electron Gun

DOE Grant No. DE-FG05-94ER86003
Amount: $97,764

A novel electron source is planned to generate a reliable and rugged high-current electron beam for use in klystrons, gyrotrons, and high brightness electron sources for accelerators. This high-density, long-life electron gun avoids the difficulties associated with plasma cathodes, thermionic emitters, and field emission cathodes. This concept employs the emission of secondary electrons in a transmission mode as opposed to the conventional reflection mode. Hence, electrons exit from the back face of a thin negative electron affinity (NEA) material in the same direction as the incident beam. Current amplification through one stage of an NEA material could be up to a thousand fold. The amplification is accomplished in one or more stages. The first stage is a low current density (≤ 1 A/cm^2) robust emitter (e.g., Lanthanum Hexaboride, Tungsten, or thoriated Tungsten). The sequential stages are thin NEA electrodes which emit secondary electrons in the same direction as the incident beam from the previous stage. A practical device will be designed at 100 kW of average power based on this concept. In Phase I an assessment will be made of the material requirements of the electrodes. Also, the effects on the device of space charge, cathode poisoning, sputtering, electrode shapes, bias voltage, and heating will be evaluated. In Phase II a full-scale prototype will be designed, fabricated, and tested.

Anticipated Results / Potential Commercial Applications as described by the awardee: If successful, this robust high-current electron gun should provide a high peak power, multi-kiloampere, long-lived electron beam (either pulsed or dc) which would be suitable for commercial and research electron beam applications including microwave generation and high-brightness sources for accelerators.

10

Small Business
JP Accelerator Works
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Los Alamos, NM 87544
Dr. James M. Potter, Principal Investigator
and Business Official
(505) 662-5804

Research Institution
Los Alamos National Laboratory
Accelerator Operation and Technology
P.O. Box 1663, MS H851
Los Alamos, NM 87545

A 500 Megawatt Microwave Free Electron Laser

DOE Grant No. DE-FG02-94ER86021
Amount: $97,801

The object of this project is to investigate the feasibility of using a Raman regime free electron laser as the basis for a commercially producible microwave power source suitable for a large linear collider. The planned design would produce more than 500 megawatts of power with a wavelength less than 18 millimeters in pulses lasting 100 billionths of a second or more. Much research effort has gone into the development of microwave power sources at the level of 50 megawatts or higher. Fundamental problems have limited the success of previous approaches to achieving power levels greater than 100 megawatts (MW). This project will pursue innovative concepts that avoid many of the earlier problems while making it possible to achieve peak power levels approaching 1,000 megawatts at wavelengths from 3 to 30 millimeters. These problems should be overcome by using a microwave free electron laser (FEL) in the reverse field configuration. A cylindrical hollow electron beam, nearly the diameter of the beam pipe, combines low power density with a high beam current limit and improves efficiency. Good phase stability is achieved by operating with the output wavelength near the beam pipe cutoff wavelength. A transversely slotted beam pipe may make it possible to build a self-excited microwave FEL, eliminating the magnets normally required. The slots are arranged so that the uncut portion forms a conductor spiraling around the beam pipe axis, forcing the return beam current to spiral around the beam and producing a magnetic field similar to the normal free electron laser wiggler field. The slots also provide an additional benefit by inhibiting power loss due to conversion of beam energy into microwave energy at undesired wavelengths. The project is directed at establishing the microwave free electron laser as the most cost-effective way to provide high microwave power to a linear collider.

Anticipated Results Potential Commercial Applications as described by the awardee: The successful development of a 500 MW microwave free electron laser would result in a significant decrease in the cost of constructing a 1 TeV level linear collider by greatly reducing the number of radio frequency (RF) power devices required. The application requires hundreds to thousands of gigawatts of microwave RF power in the 10-35 GHz range. A 0.5 to 1 GW RF power source makes it more economically feasible to build a large linear collider. The peak power and energy per pulse that can be developed by the FEL could reach levels of interest in the defense community.

11

Small Business
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Albuquerque, NM 87112
Dr. Richard J. Adler, Principal Investigator
and Business Official
(505) 296-3596

Research Institution
Stanford Linear Accelerator Center
Klystron and Microwave Department
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Menlo Park, CA 94025

An Efficient, Low Cost Power Modulator System for High Power Klystrons

DOE Grant No. DE-FG02-94ER86020
Amount: $96,816

Future linear colliders will require a large number of pulsed microwave sources which, when the cost of the associated power modulators is included, represent a considerable fraction of the machine's total cost. The line type modulators which have traditionally been used to power klystrons will, if used, lead to an inefficient power system which will significantly increase the operation cost of the collider. The short pulse required for the collider leads to a modulator system in which a disproportionate amount of the pulse energy is wasted in the rise and fall times of the pulse. In this project an alternate approach is planned which offers the possibility of lower capital and operating costs. The "Nested High Voltage Generator" (NHVG) technology, when combined with a klystron which uses a gridded gun, virtually eliminates rise and fall time losses. The use of DC accelerators with energy storage capability and grid control of the cathode can provide a low cost, high confidence means of generating high quality electron beams for high power Klystrons. The NHVG technology has already demonstrated efficient (>85%) conversion from the power grid to the beam energy. The recent construction and testing of a 500 kV device for $60,000 demonstrate the intrinsic low cost of the technology. To implement a combined klystron/NHVG system, the klystron must be equipped with a gridded gun, and a klystron envelope must be provided which has intermediate voltage stages as required for DC voltage hold-off. To demonstrate parameters desired in the final linear collider, efficiencies in excess of 90% must be demonstrated, and techniques must be developed for integrating the klystron and the NHVG. In Phase I a 500 kV, 280 A NHVG will be designed based on enhanced efficiency and voltage regulation research which will be based on the existing prototype. Stanford Linear Accelerator Center (SLAC) will simulate and design an appropriate gridded/graded gun which will be integral to the design of the modulator. In Phase II a prototype modulator will be fabricated, tested, and delivered to SLAC. SLAC will fabricate the gridded/graded gun as a load, and integrate it with the modulator for system evaluation.

Anticipated Results Potential Commercial Applications as described by the awardee: The NHVG/klystron combination should have significant applications as a drive system for advanced electron accelerators which have applications in advanced radiation sources (free electron lasers, for example). The NHVG by itself could have extensive applications to chemistry (electron beam cross linking and curing), medical products (sterilization), and isotope production (ion beam production of positron emission tomography).

TECHNOLOGIES IN SUPPORT OF NUCLEAR PHYSICS RESEARCH

12

Small Business
ARACOR
425 Lakeside Drive
Sunnyvale, CA 94086
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Mr. Ed LeBaker, Business Official
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Research Institution
Lawrence Berkeley Laboratory
Department of Electrical Engineering
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MS 90-1070
Berkeley, CA 94720

An Integrated X-Ray Sensor

DOE Grant No. DE-FG03-94ER86001
Amount: $97,829

Nuclear scientists have demonstrated a detector technology, based on a segmented silicon strip detector, that supports count rates of 1,000,000 cycles per second, up to 100 times faster than typical commercial liquid-nitrogen cooled Si[Li] detectors. In addition, this approach has demonstrated peak resolutions of 350 eV at 5.9 keV operating near room temperature (-5°C). However, use of this detector technology is prohibitively expensive if deployed with conventional signal processing electronics. This will be overcome, in part, by the use of bonded-wafer technology to cost-effectively integrate the multi-channel strip detector with integrated-circuit signal-processing electronics. Concurrently, the project will reduce the noise to a level that allows peak resolutions of less than 220 eV, while maintaining the same count rate capability. This should open up a route to commercialization. In Phase I a 32-channel detector will be designed, built, and tested. The x-ray response and noise performance of the integrated x-ray sensor will be initially characterized.

Anticipated Results. Potential Commercial Applications as described by the awardee: Phase I should develop an integrated x-ray sensor that demonstrates the concept and provides the data base to complete the sensor development and demonstration in Phase II. The sensor is expected to provide an attractive alternative for Si[Li] detectors and electronics used in commercial x-ray spectrometers for electron-beam microanalysis and x-ray fluorescence applications. The integrated sensor technology could also help meet the requirements of the nuclear science community.

13

Small Business
LeCroy Corporation/Jorway Corporation
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Chestnut Ridge, NY 10977-6499
Dr. Werner Farr, Business Official
(914) 578-6027

Research Institution
Yale University
12 Prospect Place
Physics Department
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Dr. Satish Dhawan, Principal Investigator
(203) 432-3377

An Extension of the CAMAC Standard for Increased Data Transfer Rates

DOE Grant No. DE-FG02-94ER86016
Amount: $96,289

CAMAC (Computer Aided Measurement and Control) is a mature standard for data acquisition systems, and is widely used in nuclear and high energy physics as well as other areas of research and engineering. The basic design of the standard was completed before 1970. The specifications reflect the state of electronics and computer technology at that time. Nevertheless, new CAMAC modules continue to be developed. CAMAC is an easy to use, low cost data acquisition system. The wide variety of modules available is one of CAMAC's greatest advantages; however, its disadvantage is speed. The maximum transfer rate of 3 Megabytes per second is simply too slow for many applications. A compatible extension to the CAMAC standard, which makes more efficient use of the existing CAMAC dataway bandwidth, will be developed in this project. This will increase the data acquisition speed to as much as 60 Megabytes per second in a series of steps starting at 6 Megabytes per second (from 2 to 20 times faster than standard CAMAC). During Phase I, the feasibility of this extension will be verified, and several possible implementations will be explored by building simple prototypes and testing them with existing CAMAC systems. This will lead to an improved definition of the planned extension and a better understanding of the maximum data rates obtainable. A proposal will be presented to the Nuclear Instrument Committee, to include this extension in the official CAMAC standard.

Anticipated Results/Potential Commercial Applications as described by the awardee: CAMAC could become suitable for a wider range of applications, and no longer be limited to low rate experiments. This could extend the life of the CAMAC standard and provide immediate economic benefits to the many laboratories and university groups (both in the U.S. and around the world) that have a large investment in CAMAC. This widening of the applicability of CAMAC could have substantial commercial benefit to the many firms producing CAMAC hardware.

FUSION TECHNOLOGY

14

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Research Institution
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Metals and Ceramics Division
P.O. Box 2008
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Dr. Lance Snead, Principal Investigator
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Improved Mineral Insulated Cables for Fusion Reactor Diagnostics

DOE Grant No. DE-FG05-94ER86002
Amount: $97,831

Magnetic diagnostics are of critical importance for the operation of tokamaks such as the proposed International Thermonuclear Experimental Reactor (ITER) machine. Such diagnostics as currently used in machines such as DIII-D are comprised of helically wound, mineral insulated cables located throughout the device. Because of the enhanced gamma and neutron flux expected in the ITER machine, analysis has shown that sensor types proposed in the Conceptual Design Phase of ITER and by the ITER Joint Central Team are basically inadequate. This project will address the central problem associated with the design of magnetic diagnostics for ITER. Specifically, mineral insulated cables will be fabricated with advanced insulation and processing to meet or exceed requirements set out by ITER. Once fabricated, cables will be tested in an irradiation environment at flux levels appropriate for the ITER diagnostic application. Advanced mineral insulated cables will be fabricated then tested in a radiation environment. These cables will be evaluated for leakage current and noise for application as magnetic field sensors in nuclear reactor environments.

Anticipated Results/Potential Commercial Applications as described by the awardee: A reduction in conductivity of one to two orders of magnitude at ITER flux levels is expected. Successful cable designs should be of benefit in diagnostic application wherever a radiation environment exists including Commercial Nuclear Power Stations as well as research accelerator and fusion reactor installations.

15

Small Business
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Laboratory, Inc.
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Research Institution
Lawrence Livermore National Laboratory
Electronics Engineering Department
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A Microcalorimeter for High Resolution, Broad Band X-Ray Spectroscopy of Tokamak Plasmas

DOE Grant No. DE-FG03-94ER86010
Amount: $97,83100

A promising new silicon thermistor technology has been discovered that may make it feasible to field a microcalorimeter as a high resolution, broad band x-ray diagnostic for a neutron-rich tokamak plasma. The thermistor is epitaxially grown and doped by chemical vapor deposition. The process is directed at fabricating uniform, multi-element silicon thermistor arrays as transducers for microcalorimeters. With potential count-rate capabilities of 10^4-10^5 Hz and a resolution approaching 12,000 at 13 keV, this single instrument could provide data that currently requires several instruments to obtain. The microcalorimeter will provide high resolution spectra without the bandwidth and sensitivity limitations of a crystal spectrometer. Its susceptibility to spurious background noise from fast neutrons would be low enough to allow line-of-sight measurements of a plasma like the proposed International Thermonuclear Experimental Reactor (ITER). Microcalorimeters based on this thermistor technology will be sufficiently radiation hard, enabling them to perform for several years on ITER. The work planned for Phase I is crucial to understanding the properties and behavior of these low temperature sensors. The responsivity and heat capacity will be evaluated at temperatures between 50 and 300 mk as a function of dopant concentration and compensation fraction. The uniformity and reproducibility of the growth/doping process will also be studied by testing and comparing several samples fabricated in the same manner. The epitaxial growth method should allow exploration of a wide and previously inaccessible range of sensor parameter space in a controlled and reproducible manner.

Anticipated Results/Potential Commercial Applications as described by the awardee: A versatile method for producing doped epitaxial silicon thermistors should form the basis for making large area arrays of microcalorimeters. A spectral analysis tool with unsurpassed performance could be available for non-destructive examination of matter via x-ray fluorescence spectroscopy or proton-induced excitation (PIXE). Scanning electron microscopes can incorporate this microcalorimeter for chemical imaging and mapping. New low temperature thermometers may be available.

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Small Business
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Dr. J. C. Withers, Business Official
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Research Institution
University of Illinois at Urbana/Champaign
Department of Electrical and Computer
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1406 West Green Street
Urbana, IL 61801

Development of a Commercial High-Velocity Hydrogen Pellet Injector Using Railgun Technology

DOE Grant No. DE-FG03-94ER86009
Amount: $97,831

Titanium diboride ceramic and copper metal composite (cermet) materials are planned as railgun materials for injection of solid pellets of hydrogen and deuterium for fusion applications. These cermet materials were developed for plasma gun applications from 1991 to 1993. These cermets have exhibited exceptional physical properties, and even though they are mainly ceramic (85 volume percent titanium diboride) they have excellent electrical (8 to 10 μΩ cm), and thermal (120 to 150 W/m•°K) conductivity. These materials also have excellent mechanical properties with a strength of 1200 MPa and toughness of 15 MPa•m$^{1/2}$. Compared to copper rails, the cermet rails have shown an order of magnitude reduction in erosion, and an overall 16% increase in the acceleration force, and have prevented voltage breakdown. The high resistance to erosion, stiffness, and thermal, electrical, and mechanical properties makes this material an ideal candidate for hypervelocity railguns. In this project, test firing of solid pellets of hydrogen and deuterium will be conducted using the cermet railgun. A velocity goal of 4 to 5 km/sec is set for Phase I using a 1 to 2m rail gun. A larger diameter and longer bore will be proposed for Phase II to reach velocities of 10 km/sec.

Anticipated Results Potential Commercial Applications as described by the awardee: Low cost manufacturing of high performance cermet composites should have wide commercial potential including advanced cutting tools. Commercial railguns can be used for injection of solid hydrogen pellets for fusion reactors, stellarators, tokamak reactors and reverse-field pinches.

NUCLEAR FUEL AND ENERGY CONVERSION TECHNOLOGY

17

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Research Institution
Jet Propulsion Laboratory
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A High Efficiency Radioisotope Thermophotovoltaic Generator Design

DOE Grant No. DE-FG03-94ER86012
Amount: $97,810

Based on performance data for new infrared sensitive gallium antimonide photovoltaic cells, a radioisotope thermophotovoltaic generator can potentially operate with conversion efficiencies in excess of 20% and, therefore, with specific power densities three times higher than current radioisotope thermoelectric generators. The key to the success of these "solar" cells in such a system is their ability to respond to the longer wavelength radiation of a source that is not as hot as the sun. A new gallium antimonide derivative material has been shown to have a still longer wavelength response. Additionally, infrared filters have been fabricated to allow radiation to pass through these cells and reflect back non-useful radiation to further heat the radioisotope emitter. Another potential source of improved power density is the use of a rare earth garnet selective emitter. In Phase I a preliminary generator design study will be conducted which will cover cell receivers, filter components, emitters, and radioisotope heat sources. Trade parameters in the study will include cell bandgap energy, filter design, and emitter spectral characteristics. Sample filters and rare earth garnet selective emitters will be provided for measurements for the study's input data.

Anticipated Results/Potential Commercial Applications as described by the awardee: There are many commercial applications for a hydrocarbon heated thermophotovoltaic generator using gallium antimonide cells. Applications range from one kilowatt stand-alone generators for boats and recreational vehicles to larger ten kilowatt on-board propulsion power supplies for electric vehicles. Thermophotovoltaic cells and infrared selective filters for radioisotope heat sources will use the same production processes, so these different product lines will be synergistic.

CONTROL SOFTWARE FOR FOSSIL ENERGY APPLICATIONS

18

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Boiler Optimization Using Advanced Learning Techniques

DOE Grant No. DE-FG05-94ER86004
Amount: $97,648

Industry and power utilities use boilers that burn coal to produce steam. This steam is used for processes (industry) or to drive turbines (utilities). Current boiler controls often contribute to poor fuel efficiency and excessive air pollution because the fuel (coal) to air ratio for a given load is accomplished by crude mechanical means. This type of control may result in too much or too little air for proper combustion of the coal. Too much air reduces boiler efficiency. Too little air leads to poor fuel utilization and high carbon monoxide emissions. In addition, there are optimum air levels for minimizing nitrogen oxides emissions. Current systems require intervention by a skilled operator to produce optimum results. This project will develop a new control system based on a neural network. The new system will use sensor inputs fed into neural networks that will produce outputs to control air and fuel flow rates to maximize boiler efficiency and fuel utilization, while minimizing nitrogen oxides and carbon monoxide emissions. The system will work over the full range (low to high demand) of boiler loads. At the end of the development program, an advanced control system will be available to operators of coal-fired industrial and utility boilers that can significantly improve boiler operation in terms of fuel efficiency and minimization of pollutant emissions.

Anticipated Results/Potential Commercial Applications as described by the awardee: The neural network-based control system could be used for both industrial boilers and power utility boilers to maximize boiler efficiency and carbon conversion while minimizing NO_x and CO emissions over the full operating range of the boiler.

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Research Institution
Lehigh University
Energy Research Center
Packard Lab, No. 19
Bethlehem, PA 18015

Nitrogen Oxide Compliance and Adjustment of Coal Burners Based on Flame Frequency Spectra Analysis

DOE Grant No. DE-FG02-94ER86014
Amount: $97,831

The purpose of this project is to develop an advanced method of NO_x compliance and adjustment of coal burners by incorporating the results of flame signature analysis into a strategy for boiler tuning. The approach is based on maximum utilization of the existing plant equipment and instrumentation and avoids the capital intensive cost of equipment retrofit. In Phase I, a utility pulverized coal-fired boiler will be equipped with the means for flame frequency spectra analysis. The flame quality information from the flame spectra analysis will be related to individual burner operating settings by using advanced signal processing of temporal flame spectra. The feasibility of using the flame monitoring system to tune the burners to reduce NO_x and improve boiler performance will then be tested. In Phase II, the results will be tested on a large scale at several industrial and utility boilers equipped with different types of burners and flame scanners. In Phase III, the results will be commercialized in the form of several new products ranging from portable burner balancing and burner adjustment systems to boiler optimization and performance monitoring software packages.

Anticipated Results/Potential Commercial Applications as described by the awardee: An advanced method of NO_x compliance and adjustment of coal burners should be developed by utilizing information on flame frequency spectra and the relationships between these spectra and individual burner operating settings. The new system, based on advanced signal processing of both temporal flame spectra and NO_x compliance strategies, should add a new environmental dimension to boiler optimization techniques and could improve the performance of fossil power plants. The resulting products, which rely on existing hardware, should be inexpensive and easily installed in utility and industrial boilers.

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1220

Constraining Seismic Traveltime Tomography to Produce Optimal Layered Earth Models

DOE Grant No. DE-FG02-94ER86018
Amount: $97,171

According to recent studies by the National Petroleum Council (NPC) and the United States Department of Energy (DOE), significant gas (203 trillion cubic feet) and oil (325 billion barrels, 64% of the total original oil in place) remains trapped in existing, previously-discovered reservoirs. The resource is left behind because the earth is not simple, continuous, or homogeneous. The principal barrier to extracting bypassed oil and gas in existing reservoirs is an inadequate description of the geologic heterogeneities between wells. Three-dimensional seismic data collected from the surface of the earth provide a low-resolution view of the reservoir over a wide area, not always adequate to describe the structure and porosity/permeability variations at a scale that controls flow. Well logs and cores describe the reservoir with high resolution at the wellbore, but offer little information about reservoir properties between the wells. Crossed seismic profiling places a seismic source in a wellbore and receivers in a nearby wellbore to provide high-resolution images and formation property information between the wells. Traveltimes of the energy directly transmitted from source to receiver are used in traveltime tomography to provide a two-dimensional map of the formation velocity in the interwell region. Traveltimes and amplitudes of reflections generated at rock interfaces are used in reflection imaging to produce a detailed image of the reservoir structure. Because seismic waves with frequencies as high as a few kilohertz are typically recorded in crosswell surveys, the resolution of crosswell imaging has been demonstrated to be 10 to 100 times that of surface seismic data with vertical resolution of 5 to 10 feet or better. In current traveltime tomography methods, earth models are often described by rectangular cells (pixels), with a constant velocity within each cell. Although this formulation is appropriate for medical tomography, when applied to the crosswell configuration it leads to tomograms that suffer from artifacts. These artifacts are caused by the fact that the number of pixels is much larger than the number of measurements. Geologic interpretation of tomograms contaminated by artifacts becomes ambiguous. To address this practical difficulty, algorithms will be developed in Phase I that constrain seismic traveltime tomography by taking into account the generally highly layered structure of the earth. In Phase II the algorithms will be generalized to assure compatibility with software commonly used in the gas and oil industry.

Anticipated Results/Potential Commercial Applications as described by the awardee: The result anticipated is a more geologically correct two-dimensional velocity estimate between wells, suitable for both information property estimation and velocity estimation in reflection imaging. The result should be a prototype algorithm available to commercialize within a crosswell processing package or for use in crosswell processing services.

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Office of Research Services
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Crosswell Reflection Imaging with Amplitude Corrections

DOE Grant No. DE-FG02-94ER86019
Amount: $96,899

It has been estimated that some 203 trillion cubic feet of gas and 325 billion barrels of oil remain untapped in known reservoirs. These valuable energy sources have not been exploited because of limitations inherent in existing methods for mapping geologic dissimilarities between wells. The two most commonly used methods have shortcomings. One technique involves the collection of three-dimensional seismic data at the surface of the earth. This method covers a wide area but suffers from low resolution. Well cores, on the other hand, offer high resolution at the well but provide very limited information about the area between the wells. Both high-resolution images and geologic information between wells can be obtained by using crosswell seismic profiling, which is accomplished by placing a seismic source in one wellbore and receivers in a second nearby wellbore. Detailed images of reservoir structure can then be obtained by analyzing the signals reflected from rock interfaces for traveltime and amplitude. Crosswell reflection data will have a great impact on the design and monitoring of secondary recovery processes (water, CO_2, and steam flooding) if estimates of rock properties, such as porosity and permeability, can be made from the data. Recent advances in rock physics have demonstrated that porosity changes affect seismic wave velocities. Core measurements can be used to establish statistical relationships between porosity and permeability. Reflection amplitudes containing information about velocity and density can therefore be linked to porosity and permeability. The practical difficulty that has to be overcome is that the amplitudes of recorded crosswell reflections are affected by a number of factors dependent on the operation of the specific source receiver system used to generate the data, the well conditions, and the efficiency with which seismic energy can propagate from the well to the rock formation and vice versa. Phase I will be directed toward development and testing on real and synthetic data of amplitude correction algorithms. The result of this project will be a report describing amplitude efforts, correction algorithms, and test results. In Phase II the algorithms will be incorporated into reflection imaging software

Anticipated Results Potential Commercial Applications as described by the awardee: The result anticipated is more correctly preserved amplitude information in crosswell data. In Phase II the algorithms will be incorporated into existing crosswell reflection algorithms to provide 'true-amplitude' seismic sections for amplitude versus offset analysis, inversion for velocity, and ultimately input into reservoir forecasting models including geostatistical methods.

APPENDIX A

Alphabetical List of Awardees

Small Business | **Research Institution**

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Duly Research, Inc. *8*

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Accelerator Theory and Special Projects
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Electrokinetics, Inc. *5*

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ERC, Inc. *18*

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(615) 455-9915

University of Tennessee Space Institute
B. H. Goethert Parkway
Tullahoma, TN 37388

Small Business	Research Institution
FM Technologies, Inc. ***9***	
Dr. Frederick M. Mako, Business Official 10529-B Braddock Road Fairfax, VA 22032 (703) 425-5111	Los Alamos National Laboratory Applied Theoretical Physics Division P.O. Box 1663 Los Alamos, NM 87545
Immersion Human Interface Corporation ***6***	
Mr. Timothy A. Lacey, Business Official 2483 Old Middlefield Way Suite 160 Mountain View, CA 94043 (415) 960-6882	Ohio Supercomputer Center 1224 Kinnear Road Columbus, OH 43212
Intelligent Systems Technology, Inc. ***1***	
Ms. Carla C. Madni, Business Official 3100 Dannyhill Drive Los Angeles, CA 90064 (310) 838-4883	Los Alamos National Laboratory Advanced Engineering Technology P.O. Box 1663, MS J576 Los Alamos, NM 87545
JP Accelerator Works ***10***	
Dr. James M. Potter, Business Official 2245 47th Street Los Alamos, NM 87544 (505) 662-5804	Los Alamos National Laboratory Accelerator Operation and Technology P.O. Box 1663, MS H851 Los Alamos, NM 87545
JX Crystals, Inc. ***17***	
Dr. Lewis M. Fraas, Business Official 1085 12th Avenue Northwest Suite D8 Issaquah, WA 98027 (206) 392-5237	Jet Propulsion Laboratory Electric Power Systems Department 4800 Oak Grove Drive Pasadena, CA 91109
Kroftt-Brakston International, Inc. ***4***	
Dr. Donn R. Armstrong, Business Official 5836 Sunrise Avenue Clarendon Hills, IL 60514 (708) 655-3065	Argonne National Laboratory Energy Technology Division 9700 South Cass Avenue Argonne, IL 60439

Small Business	Research Institution
Lawrence Semiconductor Research Laboratory, Inc. ***15***	
Mr. Lamonte H. Lawrence, Business Official 2300 West Huntington Drive Tempe, AZ 85282 (602) 438-2300	Lawrence Livermore National Laboratory Electronics Engineering Department P.O. Box 808 Livermore, CA 94550
LeCroy Corporation/Jorway Corporation ***13***	
Dr. Werner Farr, Business Official 700 Chestnut Ridge Road Chestnut Ridge, NY 10977-6499 (914) 578-6027	Yale University 12 Prospect Place Physics Department New Haven, CT 06511
Materials and Electrochemical Research Corporation ***16***	
Dr. J. C. Withers, Business Official 7960 South Kolb Road Tucson, AZ 85706 (602) 574-1980	University of Illinois at Urbana/Champaign Department of Electrical and Computer Engineering 1406 West Green Street Urbana, IL 61801
Newton Scientific, Inc. ***7***	
Dr. Ruth Shefer, Business Official 7 Redcoach Lane Winchester, MA 01890 (617) 729-8553	Washington University Division of Radiation Sciences 724 South Euclid St. Louis, MO 63110
North Star Research Corporation ***11***	
Dr. Richard J. Adler, Business Official 9931 Lomas, Northeast Suite A Albuquerque, NM 87112 (505) 296-3596	Stanford Linear Accelerator Center Klystron and Microwave Department 2575 Sand Hill Road Menlo Park, CA 94025
Planar Systems, Inc. ***2***	
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References denote entry numbers

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APPENDIX B

State List of Awardees

Arizona 15, 16
California 1, 6, 8, 12
Colorado 3
Illinois 4
Louisiana 5
Massachusetts 7, 19
New Mexico 10, 11
New York 13
Oregon 2
Tennessee 14, 18
Texas 20, 21
Virginia 9
Washington 17

References denote entry numbers

APPENDIX C

Grant Application Submissions and Awards Listed by States, Territories, and Possessions

State	Number Submitted	Number Selected
Alabama	4	0
Arizona	13	2
Arkansas	5	0
California	90	4
Colorado	11	1
Connecticut	11	0
Delaware	1	0
Florida	7	0
Georgia	6	0
Idaho	3	0
Illinois	17	1
Indiana	1	0
Iowa	3	0
Kansas	2	0
Louisiana	3	1
Maryland	13	0
Massachusetts	36	2
Michigan	10	0
Minnesota	5	0
Mississippi	1	0
Missouri	7	0
Montana	1	0
New Hampshire	3	0
New Jersey	14	0
New Mexico	22	2
New York	35	1
North Carolina	3	0
North Dakota	1	0
Ohio	21	0
Oklahoma	2	0
Oregon	5	1
Pennsylvania	21	0
Rhode Island	3	0
South Carolina	1	0
South Dakota	2	0
Tennessee	20	2
Texas	32	2
Utah	9	0
Vermont	2	0
Virginia	19	1
Washington	8	1
West Virginia	1	0
Wisconsin	10	0
Wyoming	3	0

Although eligible in each case to participate, there were no submissions from Alaska, the District of Columbia, Hawaii, Kentucky, Maine, Nebraska, Nevada, Puerto Rico, the Virgin Islands, the Commonwealth of the Northern Mariana Islands, or the Trust Territory of the Pacific Islands.

APPENDIX D

Subject Index

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DEPARTMENT OF ENERGY

STTR

1995

PHASE I AND

PHASE II

AWARDS

SELECTION STATEMENT FOR PHASE I AWARDEES UNDER THE SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM FOR FISCAL YEAR 1995 (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0622)

U. S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585
MAY 26, 1995

SELECTION OF GRANT APPLICATIONS FOR NEGOTIATION OF SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM PROJECTS FOR FISCAL YEAR 1995 UNDER PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0622

This is the second year of the STTR program, a three-year pilot program created by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564). This program is similar in many respects to the Small Business Innovation Research (SBIR) program for which the DOE has held competitions for the last thirteen consecutive years. The major difference is that, in STTR, P.L. 102-564 requires the small business applicant to collaborate with a non-profit research institution that would be a subcontractor on any funded application. The small business must perform at least 40% of the work on the project, and the research institution must perform at least 30%.

An STTR Application Status Verification Panel (ASVP) was appointed to evaluate Phase I applications for the STTR program. As a former chairman of the SBIR ASVP, I am familiar with the Panel's evaluation procedures and its methodology. I have received reports from the Technical Topic Managers (TTMs) who were responsible for the review of the 8 technical topic areas listed in the solicitation. I believe that the Panel and the TTMs have proceeded in accordance with applicable laws and regulations, that the evaluation has been thorough and equitable, and that the information presented forms a sound basis for selection. Consequently, I have selected 18 applications received under this solicitation for negotiation for award of Phase I Fiscal Year (FY) 1995 STTR grants. This statement describes the procurement and sets forth the basis for my selection decision.

Procurement Description

Public Law 102-564 requires that each Federal agency with an extramural research or research and development budget exceeding $1 billion establish an STTR pilot program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector and in non-profit research institutions. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies are as follows:

Fiscal Year	SBIR Set Aside (%)
1994	0.05
1995	0.10
1996	0.15

Public Law 102-564 also prescribes that the STTR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the STTR program. This phase will have a period of performance which is typically nine months in duration. Awards will be up to $100,000 for Phase I projects. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $500,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-STTR funded Federal contracts for products or services intended for use by the U.S. Government.

Applications Received

Outreach efforts for the DOE STTR program were considerable. DOE mailed out approximately 13,000 1995 solicitations to those on an extensive mailing list used for the SBIR program, and to other individuals requesting copies. In addition, the STTR solicitation was advertised in the Commerce Business Daily on September 14, 1994. It also received coverage in trade journals and newsletters and in various Small Business Administration information releases and conferences.

A total of 177 applications were received in response to the solicitation. The solicitation listed 8 technical topic areas to which applicants could respond. The list of technical topic areas and the number of applications received in each area are as follows:

1. Production and Conversion of Cellulosic Biomass to Alternative Fuels	13
2. Biotechnology: Resources and Applications	19
3. Environmentally Benign Physical and Chemical Processes	39
4. Fusion Technology	22
5. Specialized Components for and Research on High Energy Accelerators	24
6. Technology in Support of Nuclear Physics Research	9
7. Analytic and Control Software for Fossil Energy Applications	44
8. Miniaturized Coolers and Electronics for Nonproliferation Radiation Detection Instruments	6

One application received could not be assigned to a specific topic or subtopic.

Of the 177 applications received, 12 were eliminated for administrative reasons; DOE staff determined that these applications failed to meet one or more material requirements of the solicitation.

The remaining 165 were judged on a competitive basis in a two-step process. The first step of that process was a screening by the TTMs and DOE staff knowledgeable in the topic area to determine the relevance of each application to a chosen topic by the extent to which it responded to a specific topic area. Then it was determined whether each application was for research or research and development, whether it provided sufficient information for a full evaluation, whether it was duplicative of other ongoing or previous efforts, and finally, whether it was of sufficiently high quality for award. Sixty-three applications were eliminated after the first step technical review. The 102 applications found to be relevant were evaluated in the second step according to criteria listed in the solicitation and set out below.

Selection Criteria and Rationale

Phase I awards were made on scientific and technical merit based upon the criteria listed below. Approximately equal consideration was given to each of the following criteria:

(1) The scientific/technical quality of the research in the Phase I grant application.

(2) The degree of innovation demonstrated by the grant application.

(3) The qualifications of the Principal Investigator, other key staff, and consultants, if any, and the level of adequacy of available or obtainable instrumentation and facilities.

(4) The anticipated benefits, technical and/or economic, of the proposed research (Phase I and Phase II), if successful, with special emphasis on the likelihood that the project will attract further funding for product or process development after the STTR support expires.

(5) The soundness and level of adequacy of the Phase I proposed work plan to show progress toward proving the feasibility of the concept.

For each of the 8 technical topic areas listed in the solicitation, there was a TTM who, along with reviewers both internal to DOE and external - selected from among DOE Laboratory personnel, university researchers, and private industry personnel - evaluated and scored applications against the assigned criteria. Reviewers were selected in accordance with conflict of interest policies which have been used for the SBIR program. In addition, for STTR, no person affiliated with a research institution was allowed to review a grant application that named that research institution as a participant.

An additional score, based on the value of the proposed work to the DOE program area responsible for the topic, was assigned by the TTM and added to the score based on the five criteria addressed by the reviewers, to make a total score for each application. This sixth score was given the same weight as the scores for each of the other five criteria.

A representative from each DOE technical program area reviewed the scoring for all grant applications within the program area and ranked them by total score. Each representative then designated as highest priority, a set number of grant applications (the number is determined by the SBIR Program Manager, based on a program area's budgetary contribution to SBIR) with the highest total scores.

An Application Status Verification Panel (ASVP), consisting of technical staff from both within and without DOE, was established to ensure relative uniformity, across all DOE technical program areas, of the scoring and to ensure that scores were based on meaningful technical reviews. The ASVP was also chartered to ensure that there was consistency of scoring within topics. However, the sixth criterion, on value to the program, was not subject to ASVP review.

I have examined the evaluation documentation presented by the TTMs and the DOE technical program areas. I have also carefully reviewed the recommendations of the ASVP and have agreed that the evaluations of the TTMs and the technical program representatives and the recommendations of the ASVP provided valid bases upon which to make a selection. Therefore, based on those recommendations, and in consideration of applications whose funding would contribute to a programmatically-balanced set of SBIR-supported projects, I have selected 18 applications for negotiations. These include 12 applications that were designated as highest priority by the technical program representatives. The other 6 applications selected for award were from the remaining applications which were not designated as highest priority. Within this group of applications that were not designated as highest priority, all of those that received the highest technical rating or were within one point of such a rating were selected for award. It is my view that these applications represent outstanding technical quality and are worthy of selection for this program.

Selected Applications

Appendix A is a listing of the applications selected for negotiations leading to award. The STTR program is a three-year pilot program, and continued participation in later solicitations is strongly encouraged.

Samuel J. Barish

Samuel J. Barish
STTR Program Manager

Date: 5/26/95

Attachment:
List of Grant Applications
Recommended for Awards

APPENDIX A

DEPARTMENT OF ENERGY
SMALL BUSINESS TECHNOLOGY TRANSFER PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1995 AWARDS

Small Business Concern	Research Institution

TOPIC: PRODUCTION AND CONVERSION OF CELLULOSIC BIOMASS TO ALTERNATIVE FUELS

Bioengineering Resources, Inc. 1650 Emmaus Road Fayetteville, AR 72701	National Renewable Energy Laboratory

Project: Acid Recovery and Recycle by Solvent Extraction

HFTA 972 Grosvenor Place Oakland, CA 94610	University of California at Berkeley

Project: Membrane Separation for Recovery and Reconcentration of Acids

TOPIC: BIOTECHNOLOGY: RESOURCES AND APPLICATIONS

Applied Physics Technologies 25 East Loop Road Stony Brook, NY 11790-3350	Brookhaven National Laboratory

Project: A New Microstrip Gas Chamber for Synchrotron Biology Experiments

TOPIC: ENVIRONMENTALLY BENIGN PHYSICAL AND CHEMICAL PROCESSES

Prism Company 4 Riverview Terrace Dover, MA 02030	Boston University

Project: Environmentally Benign Manufacturing of Compact Disk Stampers

Small Business Concern	Research Institution
TDA Research, Inc. 12345 West 52nd Avenue Wheat Ridge, CO 80033	University of Akron

Project: Catalysts for Heterogeneous Alkene Hydroformylation

TOPIC: FUSION TECHNOLOGY

Plasma Processes, Inc. 4914 D Moores Mill Road Huntsville, AL 35811	Lawrence Livermore National Laboratory

Project: Laser Processing of Thermal Sprayed Beryllium Plasma Facing Components

---

Sterling Scientific, Inc. 1415 Rutledge Street Madison, WI 53703	University of Wisconsin

Project: A Plasma Source for Current Injection and Edge Biasing in Fusion Plasmas

---

Thoughtventions Unlimited P.O. Box 1310 Glastonbury, CT 06033	Oak Ridge National Laboratory

Project: Low Loss Sapphire Windows for High Power Microwave Transmission

---

TOPIC: SPECIALIZED COMPONENTS FOR AND RESEARCH ON HIGH ENERGY ACCELERATORS

Spire Corporation One Patriots Park Bedford, MA 01730-2396	Stanford Linear Accelerator Center

Project: Improved Strained-Layer Photocathodes for Spin-Polarized Electrons

---

Small Business Concern	Research Institution
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545	Massachusetts Institute of Technology

Project: Production of Jelly-Roll Process Niobium-Aluminum Superconducting Wire Using Low Oxygen Niobium Foils and Special Softening Techniques During Deformation

Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545	Ames Laboratory

Project: Investigation to Determine the Commercial Feasibility of Vanadium-Hafnium-Zirconium Laves Phase C-15 Superconductor

TOPIC: TECHNOLOGY IN SUPPORT OF NUCLEAR PHYSICS RESEARCH

Astralux, Inc. 2386 Vassar Drive Boulder, CO 80303	Lawrence Berkeley Laboratory

Project: An Advanced X-ray Detector and Detector Array

Quantrad Sensor, Inc. 2360 Owen Street Santa Clara, CA 95054	Lawrence Berkeley Laboratory

Project: Amorphous Silicon/Crystalline Silicon Heterojunctions for Nuclear Radiation Detector Applications

Small Business Concern	Research Institution
RIS Corporation 1345 Oak Ridge Turnpike Suite 324 Oak Ridge, TN 37830	Oak Ridge National Laboratory

Project: Monolithic Circuits for Barium Fluoride Detectors Used in Nuclear Physics Experiments

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TOPIC: ANALYTIC AND CONTROL SOFTWARE FOR FOSSIL ENERGY APPLICATIONS

DHR Technologies, Inc. 10400 Little Patuxent Parkway 10 Corporate Center, Suite 310 Columbia, MD 21044	George Washington University

Project: An Intelligent Controller for Optimized Sootblowing

Johanson and Associates 25 Angwen Avenue Manchester, TN 37355-9036	University of Tennessee

Project: Analytical and Control Software for Advanced and High Performance Power Systems

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Seattle Research and Training Center 4000 North Aurora Avenue Suite 2 Seattle, WA 98103	East-West Center

Project: A Visual Modeling Tool for Refinery Planning, Optimization, and Environmental Compliance

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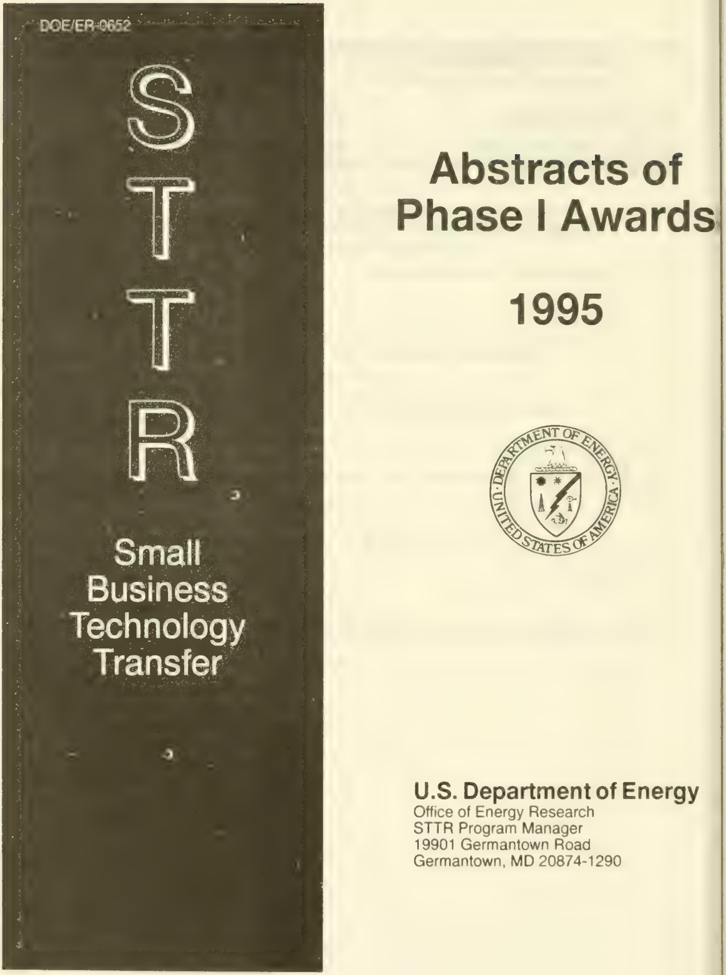
5

TOPIC: MINIATURIZED COOLERS AND ELECTRONICS FOR NONPROLIFERATION RADIATION DETECTION INSTRUMENTS

Small Business Concern	Research Institution
Stirling Technology Company 2952 George Washington Way Richland, WA 99352	Battelle Pacific Northwest Laboratory

Project: A Miniaturized Stirling Cycle/Pulse Tube Cooler for Nuclear Material Detection Systems



DOE/ER-0652

STTR

Small
Business
Technology
Transfer

Abstracts of Phase I Awards

1995

U.S. Department of Energy
Office of Energy Research
STTR Program Manager
19901 Germantown Road
Germantown, MD 20874-1290

DOE/ER-0652

STTR

Small
Business
Technology
Transfer

Abstracts of Phase I Awards

1995

U.S. Department of Energy
Office of Energy Research
STTR Program Manager
19901 Germantown Road
Germantown, MD 20874-1290

PREFACE

This booklet presents technical abstracts of Phase I awards made in Fiscal Year (FY) 1995 under the DOE Small Business Technology Transfer (STTR) program. STTR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. Brief comments on the potential applications, as described by the awardee, are given after each abstract. Individuals and organizations, including venture capital and larger industrial firms, with an interest in the research described in any of the abstracts are encouraged to contact the appropriate small business directly.

The Federal STTR Program

The STTR program, now completing its second year, was established as a three-year pilot program in compliance with the Small Business Research and Development Enhancement Act of 1992, Public Law 102-564. Five Federal agencies have STTR programs - those with extramural research and development (R&D) budgets over $1 billion. The agencies were required to set aside 0.05% of those budgets in FY 1994, 0.10% in FY 1995, and 0.15% in FY 1996 to fund STTR projects. (This amounted to about $3.4 million in FY 1995 for the Department of Energy.) Each agency solicits grant applications from small science- and technology-based U.S. firms (with 500 employees or less) in collaboration with a non-profit research institution (e.g. National laboratories and universities). Awards are made competitively to the small business with the collaborating research institution serving as a subcontractor. STTR supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about nine months, and awards are limited to $100,000. Phase II is the principal research or R&D effort, and only Phase I awardees can compete for Phase II awards of up to $500,000 in FY 1996 for work to be performed in a period of up to two years. In Phase III, commercial applications of the research or R&D are pursued using non-Federal funding or, alternatively, Phase III may involve follow-on non-STTR Federal contracts for products or services desired by the Government.

The DOE STTR Program

DOE's FY 1995 annual solicitation contained 8 technical topics in basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, energy efficiency and renewable energy, fossil energy, and nonproliferation and national security.

The 18 Phase I projects described here were selected in a highly competitive process from a total of 177 grant applications received in response to the 1995 DOE annual STTR solicitation. The selections for awards were made on scientific and technical merit, as judged against the specific criteria listed in the solicitation. Conclusions were reached on the basis of reviews performed by personnel in DOE laboratories, universities, private industry, and government. Reviewers were selected in accordance with conflict of interest policies which, for example, did not permit a person affiliated with a research institution to review a grant application that named that research institution as a participant. It is expected that between one-third and one-half of the Phase I projects will be continued into Phase II.

The DOE STTR program has the unique feature of providing for an optional early submission and rapid evaluation of Phase II applications, so that Phase II can be started without a gap in funding. A funding gap between Phases I and II can cause serious cash flow problems for small firms and is most difficult for businesses that are either new or very small. This feature, which allows continuity of funding, has been successfully provided to awardees in the DOE Small Business Innovation Research (SBIR) program for the past twelve years. Since 1984, about 40% of the SBIR Phase II awardees have had continuous funding between Phases I and II.

DOE also hopes to provide STTR Phase II awardees with the opportunity to participate in its Commercialization Assistance Program (CAP) which has been offered to SBIR Phase II awardees for the past five years. Since many small companies lack the business skills necessary for rapid commercialization of their technologies, the CAP provides successful Phase II awardees with individual assistance in developing a business plan and preparing sound and concise visual materials to describe business opportunities. The project culminates in presentations to potential sponsors, including representatives from large corporations and venture capital firms. As a result of participation in the 1991 project, SBIR companies have received more than $14 million for commercialization of their SBIR research with a projected royalty stream from option agreements of an additional $24 million over the next four years. About 43% of the firms that completed the project have received further funding for their work.

The STTR program enables DOE to obtain effective, innovative solutions to important problems through the collaboration of technology-based small businesses with non-profit research institutions. We expect that the private sector participants will have the commercial incentive to pursue the resulting technology and bring it to the marketplace.

Samuel J. Barish
STTR Program Manager
U.S. Department of Energy

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Small Business: HFTA, Oakland, CA 2
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Research Institution: University of Wisconsin

8. *Low Loss Sapphire Windows for High Power Microwave Transmission*
Small Business: Thoughtventions Unlimited, Glastonbury, CT 8
Research Institution: Oak Ridge National Laboratory

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SPECIALIZED COMPONENTS FOR AND RESEARCH ON HIGH ENERGY ACCELERATORS

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Research Institution: Stanford University

10. *Production of Jelly-Roll Process Niobium-Aluminum Superconducting Wire Using Low Oxygen Niobium Foils and Special Softening Techniques During Deformation*
Small Business: Supercon, Inc., Shrewsbury, MA 10
Research Institution: Massachusetts Institute of Technology

11. *An Investigation to Determine the Commercial Feasibility of Vanadium-Hafnium-Zirconium Laves Phase C-15 Superconductor*
Small Business: Supercon, Inc., Shrewsbury, MA 11
Research Institution: Ames Laboratory

TECHNOLOGY IN SUPPORT OF NUCLEAR PHYSICS RESEARCH

12. *An Advanced X-ray Detector and Detector Array*
Small Business: Astralux, Inc., Boulder, CO 12
Research Institution: Lawrence Berkeley National Laboratory

13. *Amorphous Silicon / Crystalline Silicon Heterojunctions for Nuclear Radiation Detector Applications*
Small Business: Quantrad Sensor, Inc., Santa Clara, CA 13
Research Institution: Lawrence Berkeley National Laboratory

14. *Monolithic Circuits for Barium Fluoride Detectors Used in Nuclear Physics Experiments*
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16. *Analytical and Control Software for Advanced and High Performance Power Systems*
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MINIATURIZED COOLERS AND ELECTRONICS FOR NONPROLIFERATION RADIATION DETECTION INSTRUMENTS

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PRODUCTION AND CONVERSION OF CELLULOSIC BIOMASS TO ALTERNATIVE FUELS

1

Acid Recovery and Recycle by Solvent Extraction

DOE Grant No. DE-FG05-95ER86031
Amount: $100,000

Small Business
Bioengineering Resources, Inc.
1650 Emmaus Drive
Fayetteville, AR 72701
Dr. Edgar Clausen, Principal Investigator
Dr. James Gaddy, Business Official
(501) 521-2745

Research Institution
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401

There are two major methods of converting lignocellulosic materials to sugars using acid hydrolysis: dilute acid treatment and concentrated acid treatment. In addition, dilute acid pretreatment is often used to solubilize hemicellulose and at least partially swell the cellulose prior to enzymatic hydrolysis. Economics dictates the recovery and reuse of the acid, even at concentrations of one percent. Researchers have developed patented technology for the recovery and recycle of both hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) by solvent extraction. This technology has been applied mainly to the recovery of acid from concentrated acid hydrolysates. This project will apply acid recovery technology to the wide range of HCl and H_2SO_4 concentrations used in dilute and concentrated acid hydrolysis and acid pretreatment. Solvent extraction experiments will be performed to determine the acid concentration range suitable for applying the technology. Acid recovery will then be applied in an enzymatic hydrolysis/fermentation experiment to identify any inhibitory effects of the solvent. Finally, the economics of applying acid recovery to various hydrolysis techniques will be projected. The subsequent Phase II research project will optimize the technology for ongoing acid hydrolysis/enzymatic hydrolysis processes.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of this simple and effective acid recovery technology should greatly improve the economics for biomass conversion to ethanol. The technology has widespread application for both concentrated acid and dilute acid processes, as well as for acid pretreatment prior to enzymatic hydrolysis. The technology should find widespread application and therefore should have significant commercial appeal.

2

Membrane Separation for Recovery and Reconcentration of Acids

DOE Grant No. DE-FG03-95ER86027
Amount: $97,358

Small Business
HFTA
972 Grosvenor Place
Oakland, CA 94610-2549
Dr. Cal Herrmann, Principal Investigator
Mr. George Craig, Business Official
(510) 893-9657

Research Institution
University of California at Berkeley
Sponsored Projects Office
336 Sproul Hall
Berkeley, CA 94720-5940

Over many years a pretreatment process has been developed for hydrolyzing wood and other cellulosic materials to constituent sugars, in large part fermentable to ethanol for use as a motor fuel additive. This work is currently in the second year of demonstration and evaluation studies, in preparation for technology transfer to industrial plant builders and operators. The pretreatment hydrolysis uses a diluted acid at elevated temperature to hydrolyze hemicellulose and reduce the residue to a powder-slurry from which the cellulosic material is further hydrolyzed to sugars and fermented. Removal (and recycling) of this acid from the products requires a separation process for which a membrane process (electrodialysis) has been proposed. Certain test and development studies must be made before the electrodialysis method can be designed into industrial-level pretreatment. Adaptation to efficient recycling of catalyst acid will apply a spiral membrane configuration, to optimize the electrical current along the transfer path, as the key improvement required. The approach in this Phase I project is to modify and apply a simulation calculation, previously developed for NASA, to the known hydrolysate composition. From these calculations an optimized electrodialysis cell will be designed, constructed, and tested with existing hydrolysates from previous pretreatment studies. Designs for integrated application to industrial fuel-ethanol plants will then be based on theory, calculations, and experiment.

Anticipated Results/Potential Commercial Applications as described by the awardee: Removal and recycling of hydrolysis acid by electrodialysis is anticipated to improve the economic practicability of the cellulose-to-ethanol conversion process. The product, as a motor-fuel additive, is in great demand. Increased supply will also reduce requirements for fuel imports, a drain on the U.S. balance of payments. The electrodialysis process will also aid in separation of byproducts of commercial value.

BIOTECHNOLOGY: RESOURCES AND APPLICATIONS

3

A New Microstrip Gas Chamber for Synchrotron Biology Experiments

DOE Grant No. DE-FG03-95ER86027
Amount: $97,358

Small Business
Applied Physics Technologies
25 East Loop Road
Stony Brook, NY 11790-3350
Dr. Argyrios Doumas, Business Official
(516) 444-8802

Research Institution
Brookhaven National Laboratory
National Synchrotron Light Source
P.O. Box 5000, Building 725B
Upton, NY 11973
Dr. David Siddons, Principal Investigator
(516) 282-2738

DOE has expressed an interest in developing new detector systems and approaches for use in areas such as x-ray diffraction studies. For example, crystallographic studies of chemical structures of biological macromolecules at synchrotrons and experiments using other x-ray sources may be severely constrained by the limitations of existing detectors. Detector concerns include high count rate capabilities and improved position sensitivity, energy resolution, and detector size. This project will address the problem by introducing a new design for improving the performance characteristics of Microstrip Gas Chambers (MSGCs). At present, the greatest obstacle to their widespread use as x-ray detectors is the problem of substrate charging. The approach in Phase I to solving this problem should result in an x-ray detector with large areas (4 in. diameter), superior two dimensional position sensitivity (100 μm), energy resolution comparable to proportional counters (800 eV at 5.9 keV), and stable long-term use. A readout scheme for the MSGC is also planned which should afford count rate capabilities superior to typical multiwire proportional counters (100 MHz). With the successful implementation of this design approach, the MSGC promises to be a detector capable of handling the requirements of the next generation of experiments at the new synchrotron (and other accelerator) facilities.

Anticipated Results/Potential Commercial Applications as described by the awardee: This detector will offer the biology community at synchrotrons and other x-ray sources a new detector which should meet the major performance specifications desired for the next generation of biology experiments. Its versatility as a charged particle detector will also result in its use for accelerator and reactor experiments. It also holds great promise as a detector for various nuclear medicine applications.

ENVIRONMENTALLY BENIGN PHYSICAL AND CHEMICAL PROCESSES

4

Environmentally Benign Manufacturing of Compact Disk Stampers

DOE Grant No. DE-FG02-95ER86033
Amount: $100,000

Small Business
Prism Company
4 Riverview Terrace
Dover, MA 02030-2248
Dr. Peter Ciriello, Business Official
(508) 785-2511

Research Institution
Boston University
881 Commonwealth Avenue
Boston, MA 02215
Dr. Thomas Bifano, Principal Investigator
(617) 353-5619

This project is aimed at implementing radical changes in the manufacturing process for optically encoded information disks (e.g., compact disks or CDs). The new engineering strategy uses advanced, precision manufacturing techniques to store data on ceramic CD stampers used for injection molding of polycarbonate CDs. By eliminating conventional process steps including electroforming of nickel stampers, the new process dramatically reduces toxic waste production. In addition, the new process cuts manufacturing time in half, and reduces capital and manufacturing costs. The most important and technically challenging issue in this project is developing an ultraprecision machining process for recording CD information on the new ceramic stamper. The work in Phase I includes fabrication of a full-scale CD stamper and testing it under actual injection molding.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned manufacturing technology represents an exciting opportunity for U.S. industry to participate in and benefit from the worldwide growth of CD markets. The planned process is cheaper, faster, and more reliable than former manufacturing processes, with fewer toxic waste byproducts, and should become competitive quickly. The market for which this technology is appropriate is undergoing explosive growth.

5

Catalysts for Heterogeneous Alkene Hydroformylation

DOE Grant No. DE-FG03-95ER86025
Amount: $100,000

Small Business
TDA Research, Inc.
12345 West 52nd Avenue
Wheat Ridge, CO 80033-1916
Dr. Girish Srinivas, Principal Investigator
Mr. John D. Wright, Business Official
(303) 422-7819

Research Institution
University of Akron
138 Fir Hill
Akron, OH 44325-2102

Alkene hydroformylation is the reaction of an alkene with synthesis gas (carbon monoxide/hydrogen) to form aldehydes. Current worldwide production of aldehydes and alcohols from hydroformylation exceeds five million tons/year. The aldehydes are primarily hydrogenated to alcohols which are used to make plasticizers, solvents, diluents, and agricultural products. Both cobalt (Co) and rhodium (Rh) carbonyl complexes are active for hydroformylation; the Rh complexes are 10^2 - 10^4 times more active than the Co complexes. However, the homogeneous process has the following two major problems: (1) Since the catalyst and the products of the reaction are in the same phase, catalyst recovery needs to be accomplished by energy intensive distillation processes. (2) Excess phosphene ligands and the carbonyl complex catalysts used are extremely toxic, making the process environmentally unfriendly. The problems associated with homogeneous hydroformylation may be solved if the reaction is carried out in the vapor phase over a solid catalyst. Prior efforts at heterogenizing the process using inert carriers for the complexes have failed because of poor stability of the catalysts and low aldehyde selectivity. In Phase I a novel class of promoted Rh catalysts will be synthesized. The catalysts will be characterized and their activity towards alkene hydroformylation and aldehyde selectivity will be investigated. Finally, an engineering analysis will be performed to determine the economic and environmental benefits derived from using these novel catalysts instead of the conventional homogeneous catalysts in the solvent-based system.

Anticipated Results/Potential Commercial Applications as described by the awardee: The development of an active and highly selective heterogeneous hydroformylation catalyst would provide both economic and environmental advantages over existing homogeneous processes. The heterogeneous catalyst will eliminate the need for elaborate catalyst recovery and catalyst losses and render the process environmentally benign. Successful development of the catalyst may also have an impact on homogeneous methanol carbonylation.

FUSION TECHNOLOGY

6

Laser Processing of Thermal Sprayed Beryllium Plasma Facing Components

DOE Grant No. DE-FG05-95ER86030
Amount: $99,975

Small Business
Plasma Processes, Inc.
4914 D Moores Mill Road
Huntsville, AL 35811-1558
Ms. Erin Richardson, Principal Investigator
Mr. Timothy McKechnie, Business Official
(205) 851-7653

Research Institution
Lawrence Livermore National Laboratory
P.O. Box 808, MS L454
Livermore, CA 94551

In-situ repair methods for advanced, next generation fusion energy devices, such as the International Thermonuclear Experimental Reactor, are needed by DOE. A primary concern is the repair of plasma facing components (PFCs). Thermal spray processes, such as inert plasma spray and vacuum plasma spray, are being investigated as a method of in-situ repair for PFCs. However, as-sprayed deposition densities of thermally sprayed materials (beryllium, tungsten) and the corresponding thermal conductivities have proven unacceptable. In this project it is planned to consolidate thermally sprayed beryllium PFCs using laser processing techniques. The laser consolidation process will melt and rapidly solidify the thermally sprayed beryllium providing a dense, fine-grained microstructure. Densities, material properties, and thermal conductivity approaching those of wrought beryllium are anticipated from the laser consolidated beryllium deposits. Density measurements of the processed beryllium will be made and compared to the as-sprayed condition. Phase II will consist of expanding laser processing parameters, investigating rapid laser processing of large thermally sprayed PFCs, and completing mechanical and thermal testing of laser consolidated beryllium.

Anticipated Results/Potential Commercial Applications as described by the awardee: Applications of laser consolidation include: fusion reactor components, thermal barrier coatings, high temperature furnace crucibles, rocket engine combustors, beryllium mirrors, corrosion protection of equipment in chemical plants, food processing facilities, oil refineries, automotive, aircraft, and marine systems, underground storage tanks, infrastructure, and biomedical implants.

7

A Plasma Source for Current Injection and Edge Biasing in Fusion Plasmas

DOE Grant No. DE-FG02-95ER86037
Amount: $92,562

Small Business
Sterling Scientific, Inc.
1415 Rutledge Street
Madison, WI 53703-3834
Mr. Thomas W. Lovell, Business Official
(608) 262-4643

Research Institution
University of Wisconsin
Department of Physics
1150 University Avenue
Madison, WI 53706
Dr. John Sarff, Principal Investigator
(608) 262-7742

This project aims to develop high current, low impurity, electron injectors, based upon emission from a plasma, which are well-suited for plasma control in large fusion devices. A range of innovative plasma control techniques have been introduced which are based on electrostatic injection of current into plasmas, e.g., current drive, current profile control, and particle and impurity control. In Phase I, a novel, inexpensive, working prototype injector will form the basis for extension to these applications. Non-fusion applications could also benefit from this compact source which produces high quality, mostly-ionized plasma streams as well as high current electron (and ion) beams. Several advantages can be realized through current emission from plasma sources rather than material sources like thermionic emitters. In particular, preparing sources of about 1 kA current and about 1 kA/cm^2 current density with small impurity content is routine. Emission from a plasma allows the source to be enclosed in low Z refractory materials suitable for immersion in hot, dense plasmas.

Anticipated Results/Potential Commercial Applications as described by the awardee: A plasma-based current source with large current density and low impurity content could be used for plasma control in large fusion plasmas. The high current, low impurity, and compactness of the source should make it well-suited for non-fusion applications requiring a high quality plasma or beam source.

8

Low Loss Sapphire Windows for High Power Microwave Transmission

DOE Grant No. DE-FG02-95ER86038
Amount: $100,000

Small Business
Thoughtventions Unlimited
P.O. Box 1310
Glastonbury, CT 06033-6310
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and Business Official
(203) 657-9014

Research Institution
Oak Ridge National Laboratory
Fusion Energy Division 9201-2
P.O. Box 2009
Oak Ridge, TN 37831

Vacuum windows that transmit high power microwave/radiofrequency energy in the 100-200 GHz frequency range are necessary for plasma heating for nuclear fusion. Current window technology will soon be inadequate for continually increasing generated power levels that now approach 1 MW. Major improvements in microwave window power capabilities can be achieved by using strengthened sapphire in a stress-relieving mount. Furthermore, a testing apparatus will permit high power testing of the windows without expensive microwave drivers. Single crystal sapphire can be a mechanically equivalent replacement for high strength steel by processing the sapphire surface for strengthening, using special mounting techniques, and minimizing thermal stresses. Small, properly mounted, strengthened sapphire windows have already been experimentally demonstrated to have a design strength that is a factor of 10 more than the current commercial specifications for sapphire. Thinner windows will greatly reduce microwave power absorption so that higher power systems can be used. This project will construct and test a generic sapphire microwave transmission window fixture. A preliminary mechanical, thermal, and cooling design for a sapphire membrane window fixture will be performed that is appropriate for high power microwave transmission. Sapphire discs will be polished and inspected to demonstrate experimentally the feasibility of fabricating large, strengthened sapphire windows. A microwave window fixture will be constructed that can demonstrate greatly improved performance as a result of stress relieving design and material strengthening procedures. A high power microwave apparatus will be developed that can be used to test microwave windows. The window design, the window fixture, and the testing procedure will then be evaluated to establish the feasibility of these concepts and their use for Phase II development and experimental testing of a prototype large microwave window fixture.

Anticipated Results/Potential Commercial Applications as described by the awardee. Ultrathin sapphire microwave windows would enable much greater single-aperture microwave power to be transmitted. Increases in injected power are both projected and needed for the advancement of plasma nuclear fusion development.

SPECIALIZED COMPONENTS FOR AND RESEARCH ON HIGH ENERGY ACCELERATORS

9

Improved Strained-Layer Photocathodes for Spin-Polarized Electrons

DOE Grant No. DE-FG02-95ER86035
Amount: $99,910

Small Business
Spire Corporation
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Mr. Richard S. Gregorio, Business Official
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Research Institution
Stanford University
Stanford Linear Accelerator Center
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Stanford, CA 94309

Polarized-electron photocathodes are a vital component of electron colliders such as those at the Stanford Linear Accelerator Center (SLAC), MIT Bates Linear Accelerator Center, and the Continuous Electron Beam Accelerator Facility. Recently, the operational efficiency of linear accelerators was revolutionized by attainment of polarization values near 90%, double those of previous designs. This breakthrough was achieved using epitaxial wafers. Strained-layer photocathodes were first used for high energy physics during the 1993 Stanford Linear Collider (SLC) run at SLAC. Although strained-layer photocathodes have been used successfully for high energy physics experiments, two problems requiring further investigation have been identified: the dependence of (1) polarization and (2) charge saturation on quantum efficiency (QE). While polarization near 90% is possible when the QE is very low (less than 0.01%), the maximum polarization for the SLC had been limited to about 80% because the high intensity requirement and the charge limit effect require the QE to be greater than 0.15%. New structures planned in Phase I, based on gallium indium phosphide ($Ga_{1-x}In_xP$), will improve the buffer layer by reducing the dislocation density resulting in higher active-layer strain and higher polarization. Use of a higher bandgap active layer and an optimized doping profile will increase quantum efficiency; performance of these improved photocathodes will be assessed. Phase II improvements include a Bragg reflector (to increase optical pathlength) and an in-situ zinc arsenide protective cap. Phase III commercialization will be through sales of epitaxial structures to electron-collider facilities.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned research will result in a technology for production of highly-polarized electron sources. These photocathodes are useful for all electron-collider facilities, for low-energy physics experimentation, and in such commercial applications as polarized-electron microscopes. Reliable spin-polarized photoemission sources will become available to the Federal Government and industrial customers through sale of epitaxial wafers.

10

Production of Jelly-Roll Process Niobium-Aluminum Superconducting Wire Using Low Oxygen Niobium Foils and Special Softening Techniques During Deformation

DOE Grant No. DE-FG02-95ER86032
Amount: $99,936

Small Business
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Research Institution
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This project aims at the production of multifilamentary high performance niobium aluminum (Nb_3Al) wire with excellent piece lengths using the Jelly-Roll process. These wires will have a high residual resistivity ratio copper (Cu) matrix. In Phase I special high purity Nb foils will be used in combination with an altered recrystallization procedure to allow sound wire drawing to thin Nb/Al layers. A non-Cu critical current density of 650 to 750 A/mm^2 at 12 T is anticipated with these raw material improvements alone. Small diameter round rolling will be applied in order to introduce a softening of the Nb matrix. Extended wire drawing, and with it, an enhancement of the non-Cu critical current density to well above 750 A/mm^2 at 12 T, are expected. This wire will combine high critical current densities with excellent strain tolerance compared to niobium tin (Nb_3Sn), while heat treatment times can be reduced by a factor of 10. This wire will offer clear cost benefits in the construction of high field magnets, in particular in react-and-wind type coils, and facilitate the cabling of conductors. Problems that are associated with liquid tin in internal tin Nb_3Sn wire can be avoided.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will result in production of Nb_3Al/Cu superconducting multifilamentary wire on a commercial scale. This superconducting wire with enhanced high-field critical currents and excellent strain tolerance will be an ideal candidate to be used in the superconducting magnets for accelerator, fusion (International Thermonuclear Experimental Reactor/Tokamak Physics Experiment), and nuclear magnetic resonance projects.

11

An Investigation to Determine the Commercial Feasibility of Vanadium-Hafnium-Zirconium Laves Phase C-15 Superconductor

DOE Grant No. DE-FG02-95ER86034
Amount: $100,000

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High field superconductors with current densities which are relatively insensitive to strain are being sought for application in the next generation of accelerator magnets, high frequency nuclear magnetic resonance spectroscopy magnets, and high field, small bore research magnets. One potential high field conductor is the strain insensitive and radiation tolerant superconductor - the C15 Laves phase compound vanadium(hafnium, zirconium) $V_2(Hf,Zr)$ When compared to the degradation of A15 materials in a high-stress, fast neutron environment or the impracticality of fabricating B1 materials for large scale applications, further development of C15 materials becomes attractive. A superconducting magnet wound with $V_2(Hf,Zr)$ wire could possibly generate magnetic fields greater that 20 T. The workability of alloys used to fabricate Laves phase superconductors and the high reaction temperatures required to form the compound have been a hindrance to extensive development of these materials. This can be overcome, however, by (1) using a composite of circumferentially wound, ductile elemental foils, or prealloyed sheets, mechanically supported by an outer shell and core which co-reduces well with the foils, and by (2) employing the shortest possible diffusion distance to minimize reaction times at the lowest possible temperature that still produces the desired phases. The lower reaction temperatures will lead to finer Laves phase grain sizes and improved performance. In Phase I six billets varying in core size, external sheath material, and composition will be assembled and processed to wire. Four billets will consist of elemental foils and two of prealloyed sheets. A series of reaction heat treatments will be conducted, and the wires will be tested for transition temperature (T_c) and critical current. The Laves phase formation will be characterized by scanning electron microscopy, transmission electron microscopy, Auger spectroscopy, and x-ray diffraction.

Anticipated Results/Potential Commercial Applications as described by the awardee. Successful completion of Phase I will build a foundation for further research in Phase II consisting of the development of a fully stabilized multifilament Laves phase superconductor and optimization of T_c, current density, and upper critical field. The fabrication process will be scaled up to full size commercial billets. While high field accelerator magnets is the principal application for C15 superconductors, a commercially available conductor would meet many of the future conductor requirements in the areas of fusion power, nuclear spectroscopy, and high field laboratory solenoids.

TECHNOLOGY IN SUPPORT OF NUCLEAR PHYSICS RESEARCH

12

An Advanced X-ray Detector and Detector Array

DOE Grant No. DE-FG03-95ER86024
Amount: $99,998

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In this project, it is planned to develop x-ray detectors based on wide bandgap semiconductor alloys that need no cooling. Such detectors have the potential to surpass the performance of cooled lithium-diffused germanium detectors, but will be able to work at room temperature or even at higher temperatures. Without complications caused by cooling, such detectors can be built into large area arrays. In Phase I, the semiconductor will be grown on a nearly lattice-matched substrate. Photoconductivity and other electrical measurements will be performed to determine whether the resistive semiconductor will be a good detector material. The x-ray response of the detector and the radiation hardness of the component materials will be evaluated.

Anticipated Results/Potential Commercial Applications as described by the awardee: Successful completion of the project will lead to x-ray detectors and detector arrays benefiting many areas in both federal and commercial sectors. The benefits will extend to nuclear physics research, x-ray crystallography, radiography, x-ray and gamma-ray astronomy, and environmental monitoring. They include sensitive x-ray detection without photomultiplier and cryogenic cooling; a large-area detector array as an electronic film substitute for x-ray crystallography and radiography; detectors for airborne radiation survey systems, and for x-ray and gamma-ray astronomy without the added weight, cost, and energy consumption due to microcoolers; and environmental monitoring with the possibility of unattended operation.

13

Amorphous Silicon/Crystalline Silicon Heterojunctions for Nuclear Radiation Detector Applications

DOE Grant No. DE-FG03-95ER86026
Amount: $99,786

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Amorphous silicon has been the subject of extensive research over the past decade with solar cells and thin film transistors being the major focuses. Most of the research has been directed toward improving growth processes to reduce deleterious bulk defects. Amorphous silicon/crystalline silicon (a-Si/c-Si) heterojunctions on high resistivity silicon, which are the focus of this project, have received scant attention in this arena. However, recent experience suggests that significant improvements in silicon detector technology can be realized by incorporating a-Si/c-Si heterojunctions into many detector designs. These heterojunctions have the advantages of low temperature processing and rugged positive-negative junctions, not matched by present day silicon detector junction fabrication technologies. The use of this heterojunction technology offers the potential of improving detector sensitivity, lowering detector production costs, and promoting additional detector innovation. The goals for Phase I are the growth and characterization of amorphous silicon films and heterojunctions formed by three different deposition techniques: plasma enhanced chemical vapor deposition, low pressure chemical vapor deposition, and radiofrequency sputter deposition. It is expected that at the completion of Phase I specific recommendations will be made on a-Si deposition procedures and equipment for silicon detector fabrication using this heterojunction technology, thereby facilitating progress on the more complex detectors that are planned for Phase II. The stated goals for Phase II include the fabrication of such devices as thick segmented silicon detectors, silicon drift detectors, and higher sensitivity silicon x-ray detectors.

Anticipated Results/Potential Commercial Applications as described by the awardee: A new generation of silicon semiconductor nuclear particle counters based on a-Si/c-Si heterojunctions will reduce detector fabrication costs and promote new detector designs. In particular, segmented silicon detectors and silicon drift detectors, which typically have low yields and high production costs, will benefit from this heterojunction technology.

14

Monolithic Circuits for Barium Fluoride Detectors Used in Nuclear Physics Experiments

DOE Grant No. DE-FG03-95ER86026
Amount: $99,786

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Research Institution
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Physics Division
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Custom monolithic electronic circuits have been developed recently for high energy physics large detector applications where subsystems require tens of thousands of channels of signal processing and data acquisition. In the design and construction of these enormous detectors, it has been found that monolithic circuits offer significant advantages over discrete implementations through increased performance, flexible packaging, lower power, and reduced cost per channel. Much of the integrated circuit design for the high energy physics community is directly applicable to intermediate energy heavy ion and electron physics. This project will develop a new integrated circuit chip set for barium fluoride (BaF$_2$) detector arrays based upon existing composite metal oxide semiconductor (CMOS) monolithic circuit designs created for the high energy physics experiments. BaF$_2$ has become the detector of choice in intermediate energy heavy-ion and electron physics. The complexity of signal processing required for BaF$_2$ makes it very expensive and intricate to implement with conventional commercial electronics on even the modest scale (<1000 channels) required for heavy ion physics. Electronic building blocks of preamplifiers, fast shaping amplifiers, constant fraction discriminators, summing amplifiers, calibration pulsers, digital-to-analog convertors, time-to-amplitude convertors, and analog-to-digital convertors have been implemented in a 1.2-micron CMOS technology for high energy physics experiments. These can be reconfigured for BaF$_2$ or other scintillator-based signal processing requirements. The completion of this development will result in a custom integrated circuit chip set which will significantly improve the performance, size, and cost per channel of the signal processing functions such as required for BaF$_2$ detector systems. This development will result in residual design shells that can be reconfigured for future research experiments and used to improve commercial signal processing applications.

Anticipated Results/Potential Commercial Applications as described by the awardee: This project will make available integrated electronics which will extend and simplify the capabilities to process BaF$_2$ or similar detector signals. This will enhance research efforts at the Holifield Radioactive Ion Beam Facility, and other experimenters throughout the world using BaF$_2$ arrays for nuclear physics experiments, such as the Two-Arm-Pion-Spectrometer collaboration in Europe, will be interested in the enhanced performance and cost savings of such integrated electronics.

ANALYTIC AND CONTROL SOFTWARE FOR FOSSIL ENERGY APPLICATIONS

15

An Intelligent Controller for Optimized Sootblowing

DOE Grant No. DE-FG02-95ER86036
Amount: $100,000

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Research Institution
George Washington University
Office of Sponsored Research
2121 I Street, N.W.
Room 601
Washington, DC 20052

The primary impediment to sootblowing optimization has been the difficulty associated with modeling the relationship between sootblowing and boiler efficiency. New advances in neural networking technology now provide an attractive approach to address this issue. This project involves a plan to develop and demonstrate an optimized sootblowing scheduler and closed-loop controller for coal-fired boilers. The intelligent controller for optimized sootblowing (ICOS) will incorporate a neural network process model and optimization algorithm to provide closed-loop, optimized control of steam or compressed air sootblowers for fossil utility boilers. ICOS will address four key sub-problems to provide optimized sootblowing: (1) calculation of sootblowing performance measures (i.e., boiler cleanliness factors) using readily available process instrumentation, (2) modeling the boiler and the relationship between operator controllable parameters and efficiency using neural networks, (3) calculation of the steady state optimal setpoints for the boiler, and (4) determination of the optimal sootblowing schedule to achieve optimal boiler performance. In Phase I the optimization approach will be tested and validated. Phase I will quantify the expected savings for the controller and will verify the effectiveness of the planned technical approach. In Phase II, the control algorithm will be incorporated into a personal computer (PC) based software application, interfaced with a sootblowing controller, and demonstrated and tested for closed-loop, optimal sootblower control. The savings achieved through use of the ICOS controller during testing will also be quantified.

Anticipated Results/Potential Commercial Applications as described by the awardee: Efficiency losses of over 200 BTU/KWH have been attributed to sub-optimal control of sootblowers in coal-fired boilers, frequently accounting for over 80% of the controllable losses in a coal-fired boiler. For a 500 MW power plant, this translates into yearly savings of over $1M. Because of the increased use of digital control systems (DCS) in the power industry and the relative ease of interfacing DCS to PC-based controllers, it is expected that the installed cost of the Phase II ICOS product will be under $50,000, providing a very favorable cost justification for the product.

16

Analytical and Control Software for Advanced and High Performance Power Systems

DOE Grant No. DE-FG05-95ER86028
Amount: $100,000

Small Business
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25 Angwen Avenue
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Mr. Robert DuBray, Business Official
(615) 728-3229

Research Institution
University of Tennessee Space Institute
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Tullahoma, TN 37388

This project will develop an innovative software/hardware system for real time computerized coal/natural gas power plant control to attain optimal technical, economic, and environmental efficiencies for commercial operation of advanced and high performance low emissions power systems. A software program will be written and hardware modified and tested in an existing 6 million BTU/hr coal and natural gas research test facility. The software will control fuel rates, primary air and secondary air/overfired air and fuel rates (reburning) to the required operating conditions to control O_2, CO, and NO_X in a specified range, operate at NO_X levels in a specified control range, and produce the desired power. Special analyzers will be used to measure total heat rate into the boiler and control the variation in flow rate of the fuels caused by the changes that occur, such as changes in the BTU content of the fuel, in moisture in the fuel, or in other variables that affect the overall BTU/hr heat release to the steam generator. An auxiliary fuel (natural gas) will be available to compensate for the primary fuel (coal) properties, and the computer software with feedback data will determine the ratio of auxiliary fuel required to maintain efficiency and low NO_X levels. The software will be used to calculate the correct coal flow to compensate for coal property change and to increase or decrease the coal flow and natural flows to operate in the most economical and environmentally sound mode. Although the emphasis of this project will be on coal-fired fossil plants, the same logic can be applied to natural gas or low grade fuel from other processes, and all grades of oil. A utility company and an engineering/manufacturing company of utility boilers will be the industrial partners to follow this project during Phase I, and will be subcontractors during Phase II. They will assist in commercialization of the system when it is developed during Phase II.

Anticipated Results/Potential Commercial Applications as described by the awardee: A software/hardware control system will be developed to control a coal-fired combustor, operate at low NO_X maximum efficiency, and automatically maintain a constant BTU/hr heat rate despite changes in the BTU content of the fuel. During Phase I the software will be developed and hardware changes made and checked out using an existing, coal-fired/natural gas test facility, and expanded and checked out for optimum control during Phase II.

17

A Visual Modeling Tool for Refinery Planning, Optimization, and Environmental Compliance

DOE Grant No. DE-FG03-95ER86023
Amount: $99,975

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Research Institution
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One of the limitations on refinery optimization is a lack of easily-used tools at the planning level. This issue has become more complicated as a result of new environmental regulations requiring fuel reformulation. This increases the complexity of blending operations, changes the relative values of feedstocks on the external market, requires the purchase of new kinds of blending agents such as oxygenates, and changes the optimum operating strategy for processing units within the refinery. Sophisticated tools are available for day-to-day operations of a refinery, but they are too complex and inflexible to be used at the planning level. Moreover, the wide differences in the form of the optimization languages used means that models are not readily comparable between government and industry, between companies, or even with different branches of the same company. Moreover, the arcane nature of structuring a refining model means that few potential users can actually apply such a model to a problem. Advances in microcomputer capabilities and object-oriented programming languages now make it possible to transform the problem of structuring a model to a visual basis. This project will develop a visual modeling tool (VMT) that allows refinery problems to be specified by drawing a flow diagram of the problem in question. This is not only far more intuitive, and therefore more easily learned, than traditional modeling languages, but is also transferable; while model structures for a single problem may vary between software packages, a problem has a single consistent flow diagram. The project will develop a prototype user-friendly, personal computer-based VMT under the Windows operating environment; a compatible linear programming-solution package and interface; and a basic, expandable database system to provide process unit vectors and blending coefficients, with particular emphasis on new environmental blending constraints, such as aromatic content, sulfur, oxygenates, ASTM 90% point, and related specifications.

Anticipated Results/Potential Commercial Applications as described by the awardee: The VMT will be easy to learn, and will cost far less than current optimization packages. This will greatly expand the number of users. The refining industry, regulatory agencies, and trading houses are obvious markets. The VMT will allow more economic purchases and easier blending in compliance with new environmental regulations and will allow more rapid estimation of costs of alternatives. It can provide a common analytical framework for industry and government when analyzing impacts of new regulatory proposals.

MINIATURIZED COOLERS AND ELECTRONICS FOR NONPROLIFERATION RADIATION DETECTION INSTRUMENTS

18

A Miniaturized Stirling Cycle/Pulse Tube Cooler for Nuclear Material Detection Systems

DOE Grant No. DE-FG03-95ER86022
Amount: $99,976

Small Business
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Battelle Pacific Northwest Laboratory
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Richland, WA 99352

It is planned to develop a miniaturized free-piston Stirling cycle/pulse tube refrigeration system which will support the development of significantly improved Nuclear Material Detection Systems (NMDS). The planned sensor cooling device (SCD) contains a number of innovative features that will allow sensor cooling to be carried out with much less input power and at lower temperatures than comparable thermoelectric systems. SCD characteristics include cooling capacities of 25 to 150 milliwatts at a temperature range of 70 to 150 K, electrical input power requirements of 3 to 6 watts, small physical size, and long maintenance-free operating life. Phase I will focus on the detailed design of an SCD to meet NMDS requirements. Because of its critical impact on the SCD design, a prototypic linear drive compressor will be fabricated and tested during Phase I.

Anticipated Results/Potential Commercial Applications as described by the awardee: Because of its small physical size and high reliability, the SCD is ideally suited to applications where size, life, and power consumption are critical. These applications include the proposed NMDS as well as other U.S. Government agency requirements such as environmental site cleanup. Commercial applications include telecommunication and computer components, medical diagnostic equipment, and advanced imaging systems.

APPENDIX A

Alphabetical List of Awardees

Small Business	Research Institution	Award Number
Applied Physics Technologies Dr. Argyrios Doumas, Business Official 25 East Loop Road Stony Brook, NY 11790-3350 (516) 444-8802	Brookhaven National Laboratory National Synchrotron Light Source P.O. Box 5000 Building 725B Upton, NY 11973	*3*
Astralux, Inc. Dr. Ethel Pankove, Business Official 2386 Vassar Drive Boulder, CO 80303 (303) 494-0670	Lawrence Berkeley National Laboratory 1 Cyclotron Road Berkeley, CA 94720	*12*
Bioengineering Resources, Inc. Dr. James Gaddy, Business Official 1650 Emmaus Road Fayettville, AR 72701 (501) 521-2745	National Renewable Energy Laboratory 1617 Cole Boulevard Golden, CO 80401	*1*
DHR Technologies, Inc. Mr. Michael Bangham, Business Official 10400 Little Patuxent Parkway 10 Corporate Center, Suite 310 Columbia, MD 21044-3510 (410) 992-4000	George Washington University Office of Sponsored Research 2121 I Street, NW, Room 601 Washington, DC 20052	*15*
HFTA Mr. George Craig, Business Official 972 Grosvenor Place Oakland, CA 94610-2549 (510) 893-7203	University of California at Berkeley Sponsored Projects Office 336 Sproul Hall Berkeley, CA 94720-5940	*2*

Award Number

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Lawrence Livermore National Laboratory
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Quantrad Sensor, Inc. ***13***

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Award Number

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Sterling Scientific, Inc. ***7***

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University of Wisconsin
Department of Physics
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Stirling Technology Company ***18***

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Battelle Pacific Northwest Laboratory
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Supercon, Inc. ***10***

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Supercon, Inc. ***11***

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TDA Research, Inc. ***5***

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	Award Number
Thoughtventions Unlimited	*8*

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APPENDIX B

State List of Awardees

State	**Award Number**
Alabama	6
Arkansas	1
California	2, 13
Colorado	5, 12
Connecticut	8
Maryland	15
Massachusetts	4, 9, 10, 11
New York	3
Tennessee	14, 16
Washington	17, 18
Wisconsin	7

APPENDIX C

Grant Application Submissions and Awards Listed by States, Territories, and Possessions

State	Number Submitted	Number Selected	State	Number Submitted	Number Selected
Alabama	4	1	New Jersey	3	0
Arizona	8	0	New Mexico	6	0
Arkansas	3	1	New York	10	1
California	25	2	Ohio	6	0
Colorado	11	2	Oklahoma	1	0
Connecticut	2	1	Pennsylvania	5	0
Florida	6	0	Puerto Rico	1	0
Georgia	2	0	Rhode Island	1	0
Idaho	2	0	South Carolina	1	0
Illinois	6	0	Tennessee	13	2
Iowa	2	0	Texas	7	0
Kansas	1	0	Utah	5	0
Maryland	3	1	Vermont	1	0
Massachusetts	17	4	Virginia	6	0
Michigan	1	0	Washington	6	2
Minnesota	1	0	West Virginia	1	0
Missouri	4	0	Wisconsin	4	1
Nevada	1	0	Wyoming	1	0

Although eligible in each case to participate, there were no submissions from Alaska, Delaware, the District of Columbia, Hawaii, Indiana, Kentucky, Louisiana, Maine, Mississippi, Nebraska, New Hampshire, North Carolina, North Dakota, Oregon, South Dakota, the Virgin Islands, the Commonwealth of the Northern Mariana Islands, or the Trust Territory of the Pacific Islands.

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SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM
(PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0605)

U.S. DEPARTMENT OF ENERGY
19901 GERMANTOWN ROAD
GERMANTOWN, MD 20874-1290
DECEMBER 20, 1995

SELECTION STATEMENT FOR PHASE II AWARDEES UNDER THE SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0605)

STTR is a three-year pilot program created by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564). This program is similar in many respects to the Small Business Innovation Research (SBIR) program for which the DOE has held competitions for the last twelve consecutive years. The major difference is that, in STTR, P.L. 102-564 requires the small business applicant to collaborate with a non-profit research institution that would be a subcontractor on any funded application. The small business must perform at least 40% of the work on the project, and the research institution must perform at least 30%.

An STTR Application Score Verification Panel (ASVP) was appointed to evaluate Phase II applications for the STTR program. As a former chairman of the SBIR ASVP, I am familiar with the Panel's evaluation procedures and its methodology. I have received reports from the Technical Project Managers (TPMs) who were responsible for the review of the grant applications. I believe that the Panel and the TPMs have proceeded in accordance with applicable laws and regulations, that the evaluation has been thorough and equitable, and that the information presented forms a sound basis for selection. Consequently, I have selected six applications received under this solicitation for negotiation for award of Phase II Fiscal Year (FY) 1995 STTR grants. This statement describes the procurement and sets forth the basis for my selection decision.

Procurement Description

Public Law 102-564 requires that each Federal agency with an extramural research or research and development budget exceeding $1 billion establish an STTR pilot program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector and in non-profit research institutions. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies are as follows:

Fiscal Year	STTR Set Aside (%)
1994	0.05
1995	0.10
1996	0.15

Public Law 102-564 also prescribes that the STTR program be implemented over a three-phase process as follows: Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the STTR program. This phase will have a period of performance which is typically nine months in duration. Awards will be up to $100,000 for Phase I projects. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $500,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-STTR funded Federal contracts for products or services intended for use by the U.S. Government.

On January 11, 1994, the Department of Energy (DOE) issued its first annual program solicitation for Phase I STTR grant applications. We received 487 applications in response to that solicitation; and on May 4, 1994, we selected 21 applications for Phase I funding, all of which proceeded to grants on July 7, 1994.

The Phase II STTR program competition is limited to successful Phase I awardees. Under DOE procedures, grant applications for Phase II could be submitted at any time when it was deemed that sufficient progress had been attained under Phase I to justify the effort to be proposed for further development under Phase II. Applicants who wanted to maintain project funding continuity from Phase I to Phase II were asked by DOE to submit their applications not later than May 9, 1995, whereas the submission deadline for proposers not seeking to preserve project continuity was August 4, 1995. Based on the 21 Phase I awards, four Phase II applications were submitted by the May 9, 1995, deadline. From this submission, one was selected for a Phase II award in June 1995.

This current selection was made from applicants not seeking to preserve project continuity and from those applications that were received by May 9, 1995, but not yet funded. Of the group, 14 were received by the August 4, 1995, deadline and three were not funded from the earlier submission, for a total of 17 applications eligible for funding at this time.

Selection Criteria

Selections for Phase II awards were made on scientific and technical merit and commercial potential based upon the criteria listed below. Criterion 1 is given twice the weight of each of the other criteria. The six criteria are as follows:

1. The scientific/technical quality of the proposed research or R&D with special emphasis on its degree of innovation.

2. The qualifications of the Principal Investigator and other key personnel to carry out the proposed work and the level of adequacy of available or obtainable instrumentation and facilities.

3. The anticipated benefits, technical and/or economic, of the proposed research, with special emphasis on the likelihood that the project will attract further funding for product or process development after the STTR support expires.

4. The degree to which the Phase I objectives were met at the time of Phase II grant application submission.

5. The soundness and level of adequacy of the Phase II proposed work plan to meet the problem or opportunity.

6. The commercial potential of the proposed research or R&D as evidenced by (a) the small business concern's record of commercializing STTR or other research, (b) the existence of Phase II funding commitments from private sector or non-STTR funding sources, (c) the existence of Phase III follow-on funding commitments for the subject of the research, and (d) the presence of other indicators of commercial potential of the idea.

In all applications selected for awards, it was demonstrated that a minimum of 40% of the work would be performed by the small business, and at least 30% of the work would be performed by the research institution.

Selection Rationale

A TPM was appointed for each of the Phase I projects resulting from successful Phase I applications. Expert reviewers including DOE Laboratory personnel, university professors, and private industry personnel were selected with the help of the TPM, and they evaluated applications against criteria 1 through 5 and 6d. The TPM then scored applications based on these reviews. An STTR Application Score Verification Panel, consisting of DOE staff and other technical personnel, was established to ensure relative uniformity of scoring across the board for these criteria and to assure that scores were based predominantly on meaningful technical reviews. The Panel was also chartered to ensure that there was consistency of scoring both within and between topics.

Criteria 6a, 6b, and 6c were evaluated by Panel members based on (non-technical) information provided in the grant applications, and a score was assigned for each of these criteria. The scores for 6a, 6b, 6c, and 6d were combined, with equal weight for each, to arrive at a single score for criterion 6. Then each application was assigned a total score based on the weighting described in the beginning of the previous section. Finally, the Panel ranked the 17 applications in order of their total scores.

I have looked at the evaluation documentation presented by the TPMs. I have also carefully reviewed the recommendations of the STTR Application Score Verification Panel and have agreed that the evaluations of the reviewers, the scoring of the TPMs, and the recommendations of the Panel provided valid bases upon which to make a selection. Therefore, based on the ranking of the Panel, I have selected five applications for negotiation for award. This brings the total number of Phase II applications selected for negotiation to six including the one selection made in June 1995. The six applications consist of all those which either had the highest possible total score or were within one point of the highest possible total score. It is my view that these applications represent outstanding technical quality and attest to the commitment of the STTR program to excellence and to the development of high technology in the small business sector.

Robert E. Berger
Acting STTR Program Manager
Date: 12/20/95

Attachments:
Appendix A: Listing of applications selected for negotiation for award.
Appendix B: Project summary of each application.

APPENDIX A

DEPARTMENT OF ENERGY
SMALL BUSINESS TECHNOLOGY TRANSFER PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1995 PHASE II AWARDS

Small Business Concern	Research Institution
ERC, Inc. 1940 Elk River Dam Road P.O. Box 417 Tullahoma, TN 37388-0417	University of Tennessee Space Institute

Project: Boiler Optimization Using Advanced Machine Learning Techniques

Small Business Concern	Research Institution
FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236	Los Alamos National Laboratory

Project: A Robust High-Current Density Pierce Electron Gun

Small Business Concern	Research Institution
*Immersion Human Interface Corporation 2158 Paragon Drive San Jose, CA 95131	Ohio Supercomputer Center

Project: A Haptic Interface for Virtual Exploration of Computational Data

Small Business Concern	Research Institution
Jorway Corporation/ LeCroy Corporation 700 Chestnut Ridge Road Chestnut Ridge, NY 10977-6499	Yale University

Project: An Extension of the CAMAC Standard for Increased Data Transfer Rates

Small Business Concern	Research Institution
Newton Scientific, Inc. 7 Red Coach Lane Winchester, MA 01890-2347	Washington University

Project: Development of Kits for the Efficient and Automated Synthesis of Copper-64 Radiopharmaceuticals

Small Business Concern	Research Institution
TomoSeis, Inc. 1650 West Sam Houston Parkway North Houston, TX 77043-3115	University of California at Berkeley

Project: Crosswell Reflection Imaging with Amplitude Corrections

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*Project provided with funding continuity following application submission by May 9, 1995

APPENDIX B
DEPARTMENT OF ENERGY
SMALL BUSINESS TECHNOLOGY TRANSFER PROGRAM
PROJECT SUMMARIES FOR GRANT APPLICATIONS SELECTED FOR FY 1995 PHASE II AWARDS

Boiler Optimization Using Advanced Machine Learning Techniques

Small Business
ERC, Inc.
1940 Elk River Dam Road
P.O. Box 417
Tullahoma, TN 37388-0417

Research Institution
University of Tennessee Space Institute
B. H. Goethert Parkway
Tullahoma, TN 37388

Industry and power utilities use boiler controls that often contribute to poor fuel efficiency and excessive air pollution because the fuel to air ratio is accomplished by crude mechanical means. This project will develop a neural network based supervisory control system for multi-burner coal fired boilers. The supervisory neural network is trained by a genetic algorithm, developed in Phase I, which optimizes its performance, in terms of maximizing fuel efficiency and minimizing pollutant emissions. In Phase II, an optical technique will be developed for determining when individual burners are operating rich or lean, in order to provide a signal to the control system for balancing the air and coal flows in each burner. Initial testing will concentrate on developing a database of flame spectra for use in developing the optical sensor, and on obtaining plant data for training the supervisory neural network. Later testing will concentrate on testing the optical sensor and implementing the control system.

Anticipated Results/Potential Commercial Applicants as described by the awardee: The new control system will optimize boiler performance to maximize fuel efficiency and minimize pollutant emissions. The system should be applicable to all industrial and utility boilers.

A Robust High-Current Density Pierce Electron Gun

Small Business
FM Technologies, Inc.
10529-B Braddock Road
Patriot Square
Fairfax, VA 22032-2236

Research Institution
Los Alamos National Laboratory
Applied Theoretical Physics Division
P.O. Box 1663
Los Alamos, NM 87545

A rugged, long-life, electron gun is required to avoid the difficulties associated with plasma cathodes, thermionic emitters, and field emission cathodes. Proof-of-principle experiments will be conducted to validate a new concept for a robust, high-current density Pierce electron gun (RPG) for use in klystrons and high brightness electron sources for accelerators. The RPG concept employs the emission of secondary electrons in a transmission mode as opposed to the conventional mode of reflection. CVD (chemical vapor deposition) diamond films will be utilized because they have shown great promise in developing high yield robust secondary emission materials. Current amplification through one stage of a negative electron affinity material like coated diamond could be over 50 times. Specific application is targeted for a klystron gun to be used by the Stanford Linear Accelerator Center, with a cold cathode at 30-40 amps/cm^2 output from the secondary emission stage, approximately two microns pulse length, and approximately 200 pulses per second. As compared to a thermionic emitter, the beam emittance is inherently lower in the RPG due to the nature of the secondary emission process. In Phase I, the effects of numerous surface physics issues were addressed, an appropriate material and thickness was determined, and a conceptual gun design was developed. Phase II is aimed at experimental verification of the gun concept, including current amplification and robustness.

Anticipated Results/Potential Commercial Applicants as described by the awardee: This high-current electron gun should provide a high peak power, and long-lived pulsed electron gun which would be suitable for microwave generation and high-brightness electron sources for accelerators and ancillary applications such as imaging and light amplification.

A Haptic Interface for Virtual Exploration of Computational Data

Small Business	*Research Institution*
Immersion Human Interface Corporation 2158 Paragon Drive San Jose, CA 95131	Ohio Supercomputer Center 1224 Kinnear Road Columbus, OH 43212

Advanced graphic display technologies have made the virtual exploration of complex models accessible to a wide user population. Unfortunately, there are few human interface tools available which allow users to interact naturally with these powerful graphical environments. To enhance the exploration and interpretation of data, this project will develop a user interface mechanism which allows natural manual interaction with three dimensional computer simulations by tracking manual gestures and providing realistic force feedback to the user. In Phase I, a haptic interface methodology and prototype hardware were developed which allow users to interact with computer simulations that not only look real, but actually feel real. In Phase II, this technology will be expanded and refined so that these powerful methods of data exploration can be brought out of the laboratory and put onto the desks of engineers, scientists, and medical professionals. An integrated simulation environment for intuitively investigating complex data will be produced. This environment will include both haptic and visual information displays that present users with a believable sense of causality when interacting with large computational data sets. A sample application to simulate the biological anatomy of the human sinus cavity will demonstrate the effectiveness of the haptic/visual modeling technology. The simulation will be so realistic in both look and feel that medical professionals will be able to use the data set for practicing manual skills associated with endoscopic surgical procedures.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned haptic/visual simulation environment should have direct commercial viability as a medical simulation and surgical training tool. The technology is also applicable to many other fields including engineering and design, scientific modeling, entertainment, and education.

An Extension of the CAMAC Standard for Increased Data Transfer Rates

Small Business	*Research Institution*
Jorway Corporation/LeCroy Corporation 700 Chestnut Ridge Road Chestnut Ridge, NY 10977-6499	Yale University Physics Department 12 Prospect Place New Haven, CT 06511

CAMAC (Computer Aided Measurement and Control) is an easy to use, low cost, mature standard for data acquisition systems. CAMAC is widely used in nuclear, high energy and plasma physics as well as other areas of research and engineering. The wide variety of modules available is one of CAMAC's greatest advantages while it's major deficiency is speed. The maximum transfer rate of 3 Megabytes per second is simply too slow for many applications. This project will develop a compatible extension to the CAMAC standard, that will increase the data acquisition speed to as much as 60 Megabytes per second in a series of steps starting at 7.5 Megabyes per second (from 2.5 to 20 times faster than standard CAMAC). Phase I verified the feasibility of this extension and produced prototype hardware. Reliable operation at rates as high as 15 Megabytes per second were demonstrated and data transfer rates as high as 60 Megabytes per second were shown to be possible with some improvements to the CAMAC dataway. Phase II will result in a complete proposal to the Nuclear Instrument Module committee to include the extension in the CAMAC standard. During phase II, several FASTCAMAC modules and controllers will be developed.

Anticipated Results/Potential Commercial Applicants as described by the awardee: CAMAC should become suitable for a wider range of applications, and no longer be limited to low rate experiments. This should extend the life of the CAMAC standard, provide immediate economic benefits to the many laboratories and university groups with large investment in CAMAC, and benefit many firms producing CAMAC hardware.

Development of Kits for the Efficient and Automated Synthesis of Copper-64 Radiopharmaceuticals

Small Business	*Research Institution*
Newton Scientific, Inc. 7 Red Coach Lane Winchester, MA 01890-2347	Washington University Division Radiation Sciences 724 South Euclid St. Louis, MO 63110

At the present time, positron emission tomography (PET) generally utilizes radionuclides with half-lives of two hours or less, which is too short for many medical applications. Radiopharmaceuticals labeled with a medium half-lived radionuclide, copper-64, have shown promise in quantifying blood flow, imaging tumors, and destroying tumor cells. However, copper-64 could only be produced using large scale university research reactors which have limited availability. This project will develop simple automated procedures for the production of a variety of novel, copper-64 labeled, radiopharmaceuticals. Phase I demonstrated the feasibility of producing copper-64 with low energy biomedical cyclotrons and that it can be used to label three types of compounds: (1) lipophilic copper chelates with potential to quantify blood flow, (2) monoclonal antibodies and antibody fragments with potential for both diagnosis and therapy, and (3) small peptides which also have potential for both diagnosis and therapy. Inexpensive modular disposable systems were designed to routinely produce these compounds for pharmaceutical use. In Phase II, these techniques will be extended to allow production of curie quantities of copper-64 on biomedical cyclotrons. Automated modules to produce the three series of radiopharmaceutical listed above will be built and tested.

Anticipated Results/Potential Commercial Applicants as described by the awardee: This project will develop automated procedures for the production of a new series of positron-emitting radiopharmaceuticals. The commercialization should include the production of modules for the preparation of three important groups of radiopharmaceuticals. These modules will be used to label the specific compounds being investigated and can be easily adapted to others of similar chemical type.

Crosswell Reflection Imaging with Amplitude Corrections

Small Business
TomoSeis, Inc.
1650 West Sam Houston Parkway North
Houston, TX 77043-3115

Research Institution
University of California at Berkeley
Office of Research Services
232 Hearst Minning Building
Berkeley, CA 94720

Valuable energy sources have not been exploited because of limitations inherent in using surface seismology to characterize oil and gas reservoirs between existing wells. Crosswell seismic profiling, which places a seismic source in a wellbore and receivers in a nearly wellbore, can provide higher resolution images and formation property information between the wells. However, surface seismology is so dominated by the utilization of amplitude information that crosswell sections, despite their improved resolution, will not be accepted by geophysical interpreters unless they preserve meaningful amplitude relationships. In Phase I, the factors affecting the amplitudes observed on real crosswell data sets were studied. Direct arrival amplitudes were accurately described by a simple deterministic model combining radiation pattern effects as well as transmission loss effects. The analysis of reflection amplitudes was improved by innovations in wavefield separation and amplitude balancing and by implementing the appropriate modeling software. In Phase II, the wavefield separation and amplitude compensation methods will be further characterized by analyzing a large number of multiple profile, long-well-offset crosswell data sets. This will improve the state-of-the-art in crosswell reflection processing, shifting the emphasis from simple feasibility demonstrations to high quality, interpretable results.

Anticipated Results/Potential Commercial Applicants as described by the awardee: This project should result in software which provides interaction and interpretation of crosswell data. Interpretation and analysis techniques on par with modern surface seismic methods should help crosswell seismic become a leading geophysical tool of the future.

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Small
Business
Technology
Transfer

Abstracts of Phase II Awards

1995

U.S. Department of Energy
Office of Energy Research
STTR Program Manager
19901 Germantown Road
Germantown, MD 20874-1290

PREFACE

This document contains technical abstracts of Phase II awards made in Fiscal Year (FY) 1995 under the DOE Small Business Technology Transfer (STTR) program. STTR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. Brief comments on the potential applications, as described by the awardee, are given after each abstract. Individuals and organizations, including venture capital and larger industrial firms, with an interest in the research described in any of the abstracts are encouraged to contact the appropriate small business directly.

The STTR program, now completing its second year, was established as a three-year pilot program in compliance with the Small Business Research and Development Enhancement Act of 1992, Public Law 102-564. Five Federal agencies have STTR programs - those with extramural research and development (R&D) budgets over $1 billion. The agencies were required to set aside 0.05% of those budgets in FY 1994, 0.10% in FY 1995, and 0.15% in FY 1996, to fund STTR projects. (This amounted to about $3 4 million in FY 1995 for the Department of Energy.) Each agency solicits grant applications from small science- and technology-based U.S. firms (with 500 employees or less) in collaboration with a non-profit research institution (e.g. National laboratories and universities). Awards are made competitively to the small business with the collaborating research institution serving as a subcontractor. STTR supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about nine months, and awards are limited to $100,000. Phase II is the principal research or R&D effort, and only Phase I awardees can compete for Phase II awards of up to $500,000 in FY 1996 for work to be performed in a period of up to two years. In Phase III, commercial applications of the research or R&D are pursued using non-Federal funding or, alternatively, Phase III may involve follow-on non-STTR Federal contracts for products or services desired by the Government.

The STTR program enables DOE to obtain effective, innovative solutions to important problems through the collaboration of technology-based small businesses with non-profit research institutions. We expect that the private sector participants will have the commercial incentive to pursue the resulting technology and bring it to the marketplace.

Robert E. Berger
Acting STTR Program Manager

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SPECIALIZED COMPONENTS FOR AND RESEARCH ON HIGH ENERGY ELECTRON ACCELERATORS

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Research Institution: Yale University

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5. *Boiler Optimization Using Advanced Learning Techniques*
Small Business: ERC, Inc. 5
Research Institution: University of Tennessee Space Institute

6. *Crosswell Reflection Imaging with Amplitude Corrections*
Small Business: TomoSeis, Inc. 6
Research Institution: University of California at Berkeley

Appendix: Alphabetical List of Awardees 7

BIOTECHNOLOGY: RESOURCES AND APPLICATIONS

A Haptic Interface for Virtual Exploration of Computational Data

DOE Grant No. DE-FG03-94ER86008
Amount: $476,760

Small Business
Immersion Human Interface Corporation
2158 Paragon Drive
San Jose, CA 95131
Dr. Louis B. Rosenberg, Principal Investigator
Mr. Timothy A. Lacey, Business Official
(415) 960-6882

Research Institution
Ohio Supercomputer Center
1224 Kinnear Road
Columbus, OH 43212

Advanced graphic display technologies have made the virtual exploration of complex models accessible to a wide user population. Unfortunately, there are few human interface tools available which allow users to interact naturally with these powerful graphical environments. To enhance the exploration and interpretation of data, this project will develop a user interface mechanism which allows natural manual interaction with three dimensional computer simulations by tracking manual gestures and providing realistic force feedback to the user. In Phase I, a haptic interface methodology and prototype hardware were developed which allow users to interact with computer simulations that not only look real, but actually feel real. In Phase II, this technology will be expanded and refined so that these powerful methods of data exploration can be brought out of the laboratory and put onto the desks of engineers, scientists, and medical professionals. An integrated simulation environment for intuitively investigating complex data will be produced. This environment will include both haptic and visual information displays that present users with a believable sense of causality when interacting with large computational data sets. A sample application to simulate the biological anatomy of the human sinus cavity will demonstrate the effectiveness of the haptic/visual modeling technology. The simulation will be so realistic in both look and feel that medical professionals will be able to use the data set for practicing manual skills associated with endoscopic surgical procedures.

Anticipated Results/Potential Commercial Applications as described by the awardee: The planned haptic/visual simulation environment should have direct commercial viability as a medical simulation and surgical training tool. The technology is also applicable to many other fields including engineering and design, scientific modeling, entertainment, and education.

Development of Kits for the Efficient and Automated Synthesis of Copper-64 Radiopharmaceuticals

DOE Grant No. DE-FG02-94ER86015
Amount: $499,611

Small Business	*Research Institution*
Newton Scientific, Inc. 7 Red Coach Lane Winchester, MA 01890-2347 Dr. Ruth Shefer, Business Official (617) 729-8553	Washington University Division of Radiation Sciences 724 South Euclid St. Louis, MO 63110 Dr. Michael Welch, Principal Investigator (314) 362-8435

At the present time, positron emission tomography (PET) generally utilizes radionuclides with half-lives of two hours or less, which is too short for many medical applications. Radiopharmaceuticals labeled with a medium half-lived radionuclide, copper-64, have shown promise in quantifying blood flow, imaging tumors, and destroying tumor cells. However, copper-64 could only be produced using large scale university research reactors which have limited availability. This project will develop simple automated procedures for the production of a variety of novel, copper-64 labeled, radiopharmaceuticals. Phase I demonstrated the feasibility of producing copper-64 with low energy biomedical cyclotrons and that it can be used to label three types of compounds: (1) lipophilic copper chelates with potential to quantify blood flow, (2) monoclonal antibodies and antibody fragments with potential for both diagnosis and therapy, and (3) small peptides which also have potential for both diagnosis and therapy. Inexpensive modular disposable systems were designed to routinely produce these compounds for pharmaceutical use. In Phase II, these techniques will be extended to allow production of curie quantities of copper-64 on biomedical cyclotrons. Automated modules to produce the three series of radiopharmaceutical listed above will be built and tested.

Anticipated Results/Potential Commercial Applicants as described by the awardee: This project will develop automated procedures for the production of a new series of positron-emitting radiopharmaceuticals. The commercialization should include the production of modules for the preparation of three important groups of radiopharmaceuticals. These modules will be used to label the specific compounds being investigated and can be easily adapted to others of similar chemical type.

SPECIALIZED COMPONENTS FOR AND RESEARCH ON HIGH ENERGY ELECTRON ACCELERATORS

A Robust High-Current Density Pierce Electron Gun

DOE Grant No. DE-FG05-94ER860003
Amount: $499,785

Small Business	*Research Institution*
FM Technologies, Inc. 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236 Dr. Frederick M. Mako, Principal Investigator and Business Official (703) 425-5111	Los Alamos National Laboratory Applied Theoretical Physics Divsion P.O. Box 1663 Los Alamos, NM 87545

A rugged, long-life, electron gun is required to avoid the difficulties associated with plasma cathodes, thermionic emitters, and field emission cathodes. Proof-of-principle experiments will be conducted to validate a new concept for a robust, high-current density Pierce electron gun (RPG) for use in klystrons and high brightness electron sources for accelerators. The RPG concept employs the emission of secondary electrons in a transmission mode as opposed to the conventional mode of reflection. CVD (chemical vapor deposition) diamond films will be utilized because they have shown great promise in developing high yield robust secondary emission materials. Current amplification through one stage of a negative electron affinity material like coated diamond could be over 50 times. Specific application is targeted for a klystron gun to be used by the Stanford Linear Accelerator Center, with a cold cathode at 30-40 amps/cm^2 output from the secondary emission stage, approximately two microns pulse length, and approximately 200 pulses per second. As compared to a thermionic emitter, the beam emittance is inherently lower in the RPG due to the nature of the secondary emission process. In Phase I, the effects of numerous surface physics issues were addressed, an appropriate material and thickness was determined, and a conceptual gun design was developed. Phase II is aimed at experimental verification of the gun concept, including current amplification and robustness.

Anticipated Results/Potential Commercial Applicants as described by the awardee: This high-current electron gun should provide a high peak power, and long-lived pulsed electron gun which would be suitable for microwave generation and high-brightness electron sources for accelerators and ancillary applications such as imaging and light amplification.

TECHNOLOGIES IN SUPPORT OF NUCLEAR PHYSICS RESEARCH

An Extension of the CAMAC Standard for Increased Data Transfer Rates

DOE Grant No. DE-FG-02-94ER86016
Amount: $498,000

Small Business	*Research Institution*
LeCroy Corporation/Jorway Corporation 700 Chestnut Ridge Road Chestnut Ridge, NY 10977-6499 Mr. Joseph Migliozzi, Business Official (914) 425-2000	Yale University Physics Department 12 Prospect Place New Haven, CT 06511 Dr. Satish Dhawan, Principal Investigator, (203) 432-3377

CAMAC (Computer Aided Measurement and Control) is an easy to use, low cost, mature standard for data acquisition systems. CAMAC is widely used in nuclear, high energy and plasma physics as well as other areas of research and engineering. The wide variety of modules available is one of CAMAC's greatest advantages while it's major deficiency is speed. The maximum transfer rate of 3 Megabytes per second is simply too slow for many applications. This project will develop a compatible extension to the CAMAC standard, that will increase the data acquisition speed to as much as 60 Megabytes per second in a series of steps starting at 7.5 Megabyes per second (from 2.5 to 20 times faster than standard CAMAC). Phase I verified the feasibility of this extension and produced prototype hardware. Reliable operation at rates as high as 15 Megabytes per second were demonstrated and data transfer rates as high as 60 Megabytes per second were shown to be possible with some improvements to the CAMAC dataway. Phase II will result in a complete proposal to the Nuclear Instrument Module committee to include the extension in the CAMAC standard. During phase II, several FASTCAMAC modules and controllers will be developed.

Anticipated Results/Potential Commercial Applicants as described by the awardee: CAMAC should become suitable for a wider range of applications, and no longer be limited to low rate experiments. This should extend the life of the CAMAC standard, provide immediate economic benefits to the many laboratories and university groups with large investment in CAMAC, and benefit many firms producing CAMAC hardware.

CONTROL SOFTWARE FOR FOSSIL ENERGY APPLICATIONS

Boiler Optimization Using Advanced Machine Learning Techniques

DOE Grant No. DE-FG05-94-ER86004
Amount: $499,908

Small Business	*Research Institution*
ERC, Inc. 1940 Elk River Dam Road P.O. Box 417 Tullahoma, TN 37388-0417 Mr. W. Andes Hoyt, Principal Investigator Mr. John T. Lineberry, Business Official (615) 455-9915	University of Tennessee Space Institute B. H. Goethert Parkway Tullahoma, TN 37388

Industry and power utilities use boiler controls that often contribute to poor fuel efficiency and excessive air pollution because the fuel to air ratio is accomplished by crude mechanical means. This project will develop a neural network based supervisory control system for multi-burner coal fired boilers. The supervisory neural network is trained by a genetic algorithm, developed in Phase I, which optimizes its performance, in terms of maximizing fuel efficiency and minimizing pollutant emissions. In Phase II, an optical technique will be developed for determining when individual burners are operating rich or lean, in order to provide a signal to the control system for balancing the air and coal flows in each burner. Initial testing will concentrate on developing a database of flame spectra for use in developing the optical sensor, and on obtaining plant data for training the supervisory neural network. Later testing will concentrate on testing the optical sensor and implementing the control system.

Anticipated Results/Potential Commercial Applicants as described by the awardee: The new control system will optimize boiler performance to maximize fuel efficiency and minimize pollutant emissions. The system should be applicable to all industrial and utility boilers.

Crosswell Reflection Imaging with Amplitude Corrections

DOE Grant No. DE-FG02-94ER86019
Amount: $499,724

Small Business
TomoSeis, Inc.
1650 West Sam Houston Parkway North
Houston, TX 77043-3115
Dr. Spyros Lazaratos, Principal Investigator
Mr. Bruce P. Marion, Business Official
(713) 461-7360

Research Institution
University of California at
Berkeley
Evans Hall
Berkeley, CA 94720

Valuable energy sources have not been exploited because of limitations inherent in using surface seismology to characterize oil and gas reservoirs between existing wells. Crosswell seismic profiling, which places a seismic source in a wellbore and receivers in a nearly wellbore, can provide higher resolution images and formation property information between the wells. However, surface seismology is so dominated by the utilization of amplitude information that crosswell sections, despite their improved resolution, will not be accepted by geophysical interpreters unless they preserve meaningful amplitude relationships. In Phase I, the factors affecting the amplitudes observed on real crosswell data sets were studied. Direct arrival amplitudes were accurately described by a simple deterministic model combining radiation pattern effects as well as transmission loss effects. The analysis of reflection amplitudes was improved by innovations in wavefield separation and amplitude balancing and by implementing the appropriate modeling software. In Phase II, the wavefield separation and amplitude compensation methods will be further characterized by analyzing a large number of multiple profile, long-well-offset crosswell data sets. This will improve the state-of-the-art in crosswell reflection processing, shifting the emphasis from simple feasibility demonstrations to high quality, interpretable results.

Anticipated Results/Potential Commercial Applicants as described by the awardee: This project should result in software which provides interaction and interpretation of crosswell data. Interpretation and analysis techniques on par with modern surface seismic methods should help crosswell seismic become a leading geophysical tool of the future.

Alphabetical List Of Awardees

Small Business	Research Institution	
ERC, Inc. Mr. John T. Lineberry, Business Official 1940 Elk River Dam Road P.O. Box 417 Tullahoma, TN 37388-0417 (615) 455-9915	University of Tennessee Space Institute B. H. Goethert Parkway Tullahoma, TN 37388	*5*
FM Technologies, Inc. Dr. Frederick M. Mako, Business Official 10529-B Braddock Road Patriot Square Fairfax, VA 22032-2236 (703) 425-5111	Los Alamos National Laboratory Applied Theoretical Physics Division P.O. Box 1663 Los Alamos, NM 87545	*3*
Immersion Human Interface Corporation Mr. Timothy A. Lacey, Business Official 2158 Paragon Drive San Jose, CA 95131 (415) 960-6882	Ohio Supercomputer Center 1224 Kinnear Road Columbus, OH 43212	*1*
LeCroy Corporation/Jorway Corporation Mr. Joseph Migliozzi, Business Official 700 Chestnut Ridge Road Chestnut Ridge, NY 10977-6499 (914) 425-2000	Yale University Physics Department 12 Prospect Place New Haven, CT 06511	*4*
Newton Scientific, Inc. Dr. Ruth Shefer, Business Official 7 Red Coach Lane Winchester, MA 01890-2347 (617) 729-8553	Washington University Division of Radiation Sciences 724 South Euclid St. Louis, MO 63110	*2*
TomoSeis, Inc. Mr. Bruce P. Marion, Business Official 1650 West Sam Houston Parkway North Houston, TX 77043-3115 (713) 461-7360	University of California at Berkeley Evans Hall Berkeley, CA 94720	*6*

DEPARTMENT OF ENERGY

STTR

1996

PHASE I

AWARDS

THE BOOK OF ABSTRACTS OF PHASE I AWARDS HAS NOT YET BEEN PREPARED. ALSO, THE PHASE II APPLICATIONS ARE CURRENTLY BEING EVALUATED, SO A LISTING IS NOT YET AVAILABLE

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SELECTION STATEMENT FOR PHASE I AWARDEES UNDER THE SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM FOR FISCAL YEAR 1996 (PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0651)

U. S. DEPARTMENT OF ENERGY
GERMANTOWN, MD 20874-1290
JUNE 20, 1996

SELECTION OF GRANT APPLICATIONS FOR NEGOTIATION OF SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM PROJECTS FOR FISCAL YEAR 1996 UNDER PROGRAM SOLICITATION ANNOUNCEMENT DOE/ER-0651

This is the third year of the STTR program, a three-year pilot program created by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564). This program is similar in many respects to the Small Business Innovation Research (SBIR) program for which the DOE has held competitions for the last fourteen consecutive years. The major difference is that, in STTR, P.L. 102-564 requires the small business applicant to collaborate with a non-profit research institution that would be a subcontractor on any funded application. The small business must perform at least 40% of the work on the project, and the research institution must perform at least 30%.

I have received reports from the Technical Topic Managers (TTMs) who were responsible for the review of grant applications submitted to the 10 technical topic areas listed in the solicitation. I also led an oversight process to assure that the review was conducted in a uniform manner. I believe that the evaluation process proceeded in accordance with applicable laws and regulations, that the evaluation has been thorough and equitable, and that the information presented forms a sound basis for selection. Consequently, I have selected 15 applications received under this solicitation for negotiation for award of Phase I Fiscal Year (FY) 1996 STTR grants. This statement describes the procurement and sets forth the basis for my selection decision.

Procurement Description

Public Law 102-564 requires that each Federal agency with an extramural research or research and development budget exceeding $1 billion establish an STTR pilot program by reserving a statutorily prescribed percentage of its budget to be awarded to promote the technical expertise and sophistication residing in the high technology, small business sector and in non-profit research institutions. (Extramural budget means the sum of the total obligation minus amounts obligated for research and research and development activities by employees of the agency in or through Government-owned, Government-operated facilities.) The prescribed percentages for those Federal agencies are as follows:

Fiscal Year	STTR Set Aside (%)
1994	0.05
1995	0.10
1996	0.15

Public Law 102-564 also prescribes that the STTR program be implemented over a three-phase process as follows:

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas in applications submitted under the STTR program. This phase will have a period of performance which is typically nine months in duration. Awards will be up to $100,000 for Phase I projects. Phase II is the principal research or research and development effort and will typically be performed during a period up to two years. The amount of these awards will be up to $500,000. Phase III is the commercial application of the research or research and development effort by small businesses with non-Federal capital and may also involve follow-on, non-STTR funded Federal contracts for products or services intended for use by the U.S. Government.

Applications Received

Outreach efforts for the DOE STTR program were considerable. DOE mailed out approximately 15,000 1996 solicitations to those on an extensive mailing list used for the STTR program, and to other individuals requesting copies. In addition, the STTR solicitation was advertised in the Commerce Business Daily on September 19, 1995. It also received coverage in trade journals and newsletters and in various Small Business Administration information releases and conferences.

A total of 232 applications were received in response to the solicitation. The solicitation listed 10 technical topic areas to which applicants could respond. The list of technical topic areas and the number of applications received in each area are as follows:

1. Remote Sensing Using Low Cost Airborne Spectral Imaging Systems	10
2. Analytic and Control Software for Fossil Energy Applications	30
3. In-Situ Bioremediation of Metals and Dense Non-Aqueous Phase Liquids	19
4. Hybrid Electric Vehicle Technology	41
5. Fusion Technology	28
6. Biotechnology: Resources and Applications	13
7. Specialized Component Research and Development for High Energy Accelerators	27
8. Technology in Support of Nuclear Physics Research	8
9. Electrolytes for Batteries and Fuel Cells	30
10. Environmentally Benign Manufacturing	22

Four applications received could not be assigned to specific topics or subtopics.

Of the 232 applications received, 11 were eliminated for administrative reasons; DOE staff determined that these applications failed to meet one or more material requirements of the solicitation.

The remaining 221 were judged on a competitive basis in a two-step process. The first step of that process was a screening by the TTMs and DOE staff knowledgeable in the topic area to determine the relevance of each application to a chosen topic by the extent to which it responded to a specific topic area. At this step, it was also determined whether each application was for research or research and development, whether it provided sufficient information for a full evaluation, whether it was duplicative of other ongoing or previous efforts, and finally, whether it was of sufficiently high quality to compete for an award in the following step of the review process. Sixty-seven applications were eliminated after the first step technical review. The remaining 154 applications were evaluated in the second step technical review according to criteria listed in the solicitation and set out below.

Selection Criteria and Rationale

Phase I awards were made on scientific and technical merit based upon the criteria listed below. Approximately equal consideration was given to each of the following criteria:

(1) The scientific/technical quality of the research in the Phase I grant application.

(2) The degree of innovation demonstrated by the grant application.

(3) The qualifications of the Principal Investigator, other key staff, and consultants, if any, and the level of adequacy of available or obtainable instrumentation and facilities.

(4) The anticipated benefits, technical and/or economic, of the proposed research (Phase I and Phase II), if successful, with special emphasis on the likelihood that the project will attract further funding for product or process development after the STTR support expires.

(5) The soundness and level of adequacy of the Phase I proposed work plan to show progress toward proving the feasibility of the concept.

For each of the 10 technical topic areas listed in the solicitation, there was a TTM who, along with reviewers both internal to DOE and external - selected from among DOE Laboratory personnel, university researchers, and private industry personnel - evaluated and scored applications against the assigned criteria. Reviewers were selected in accordance with conflict of interest policies which have been used for the SBIR program. In addition, for STTR, no person affiliated with a research institution was allowed to review a grant application that named that research institution as a participant.

An additional score, based on the value of the proposed work to the DOE program area responsible for the topic, was assigned by the TTM and added to the score based on the five criteria addressed by the reviewers, to make a total score for each application. This sixth score was given the same weight as the scores for each of the other five criteria.

A representative from each DOE technical program area reviewed the scoring for all grant applications within the program area and ranked them by total score. Each representative then designated, as highest priority, a set number of grant applications (the number is determined by the Acting STTR Program Manager, based on a program area's budgetary contribution to STTR) with the highest total scores.

Lastly, I conducted an oversight process, assisted by technical staff from both within and without DOE, to ensure relative uniformity, across all DOE technical program areas, of the scoring and to ensure that scores were based on meaningful technical reviews. (However, the sixth criterion, on value to the program, was not subject to this oversight process.)

I have examined the evaluation documentation presented by the TTMs and the DOE technical program areas. I have also carefully reviewed recommendations which ensued from the oversight process to assure uniformity. I believe that the evaluations of the TTMs and the technical program representatives and the recommendations from the oversight process have provided a valid basis upon which to make a selection. Therefore, based on these evaluations and recommendations, and in consideration of applications whose funding would contribute to a programmatically-balanced set of STTR-supported projects, I have selected 15 applications for negotiations. These include 11 applications that were designated as highest priority by the technical program representatives. The other 4 applications selected for award, all of which received the highest technical rating, were from the remaining applications which were not designated as highest priority. It is my view that these applications selected for award represent outstanding technical quality and are worthy of selection for this program.

Selected Applications

Appendix A is a listing of the applications selected for negotiations leading to award. The STTR program is a three-year pilot program, and continued participation in later solicitations is strongly encouraged.

Robert E. Berger
Robert E. Berger
Acting STTR Program Manager

Date: 6/24/96

Attachment:
List of Grant Applications
Recommended for Awards

DEPARTMENT OF ENERGY
SMALL BUSINESS TECHNOLOGY TRANSFER PROGRAM
GRANT APPLICATIONS SELECTED FOR FY 1996 AWARDS

Small Business Concern	Research Institution

TOPIC: REMOTE SENSING USING LOW COST AIRBORNE SPECTRAL IMAGING SYSTEMS

Kestrel Corporation 5921 Jefferson Court NE Suite C Albuquerque, NM 87109-3432	Sandia National Laboratories

Project: A Low Cost, Airborne, Hyperspectral Imager

TOPIC: ANALYTIC AND CONTROL SOFTWARE FOR FOSSIL ENERGY APPLICATIONS

ERC, Inc. P.O. Box 417 Tullahoma, TN 37388-0417	Oak Ridge National Laboratory

Project: Intelligent Machine Learning Analysis for Fuel Cell Operations

TOPIC: IN-SITU BIOREMEDIATION OF METALS AND DENSE NON-AQUEOUS PHASE LIQUIDS

EFX Systems, Inc. 3900 Collins Road Suite 1011 Lansing, MI 48910	Pacific Northwest National Laboratory

Project: Extraction of Metals and Radionuclides from Soils and Groundwater by In-Situ Microbial and Geochemical Solubilization and Precipitation Processes

Small Business Concern	Research Institution
Phytotech, Inc. 1 Deer Park Drive Suite I Monmouth Junction, NJ 08852-1920	Pacific Northwest National Laboratory

Project: Mobilization and Removal of Strontium and Cesuim from Soil by Chemical Treatment and Phytoremediation

TOPIC: HYBRID ELECTRIC VEHICLE TECHNOLOGY

Evans Company 33 Eastern Avenue East Providence, RI 02914	Florida Atlantic University

Project: Fuzzy Carbon Electrode Structures for Electrochemical Double Layer Capacitors

SatCon Technology Corporation 161 First Street Cambridge, MA 02142-1207	Massachusetts Institute of Technology

Project: High Speed Motor Alternators for Hybrid Electric Vehicle Energy Storage

Visual Computing Systems Corporation 9540 Highway 150 Box 250 Greenville, IN 47124-9683	Oak Ridge National Laboratory

Project: A Flywheel Motor Alternator for Hybrid Electric Vehicles

Small Business Concern

Research Institution

TOPIC: FUSION TECHNOLOGY

Charles Evans and Associates
301 Chesapeake Drive
Redwood City, CA 94063-4723

Oak Ridge National Laboratory

Project: Feasibility of Correlating Vanadium-Chromium-Titanium Alloy Weld Strength with Weld Chemistry

Radiation Science, Inc.
P.O. Box 293
Belmont, MA 02178-0002

Princeton University

Project: Development of Focussing Crystal Spectrometers for Extended X-ray Sources

Utron, Inc.
8506 Wellington Road, Suite 200
Manassas, VA 22110

Oak Ridge National Laboratory

Project: A 7 Kilometers Per Second Electrothermal Light Gas Gun Pellet Injector

TOPIC: SPECIALIZED COMPONENT RESEARCH AND DEVELOPMENT FOR HIGH ENERGY ACCELERATORS

Ferrite Components, Inc.
24 Flagstone Drive
Hudson, NH 03051

Cornell University

Project: Ultra-High Vacuum Radio Frequency Load

Small Business Concern	Research Institution
Supercon, Inc. 830 Boston Turnpike Shrewsbury, MA 01545-3301	Massachusetts Institute of Technology

Project: Cabled Monofilament Subelements for Improved Multifilament Niobium Tin Performance and Reduced Cost

TOPIC: TECHNOLOGY IN SUPPORT OF NUCLEAR PHYSICS RESEARCH

Lambda Technologies, Inc. 8600 Jersey Court Suite C Raleigh, NC 27613-4707	Oak Ridge National Laboratory

Project: An Advanced Electron Cyclotron Resonance Ion Source with Large Resonant Plasma Volume

TOPIC: ELECTROLYTES FOR BATTERIES AND FUEL CELLS

NexTech Materials, Ltd. 720 Lakerview Plaza Boulevard Suite I Worthington, OH 43085-4733	Lawrence Berkeley Laboratory

Project: Thin-Film Ceria Fuel Cells with Low Operating Temperatures

TOPIC: ENVIRONMENTALLY BENIGN MANUFACTURING

Covalent Associates, Inc. 10 State Street Woburn, MA 01801-6820	University of Missouri-Columbia

Project: Two-Phase Homogeneous Catalysis in Ionic Liquid and Liquid Solvents

RESPONSE TO QUESTIONS SUBMITTED BY
THE U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
on
The Department of Energy's FY1997 Budget Request for the Office of Energy Research

John Peoples Jr., Director
Fermi National Accelerator Laboratory
July 1, 1996

1. Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) shows the following budget outlay profile for the DOE General Science and Research programs (i.e. High Energy and Nuclear Physics): FY 1996 =978 million; FY1997 = $1.002 billion; FY1998 = $948 million; FY1999 = $865 million; FY2000 = $781 million; FY 2001 = $840 million; and FY2002 = $959 million.

What are the implications of the outyear figures, which dip as low as $781 million in FY2000, for both the domestic high energy and nuclear physics programs, and for the potential U.S. participation in the construction and operation of the Large Hadron Collider (LHC) at CERN?

Today the U.S. is among world leaders in high-energy physics, with a healthy, balanced and productive research program. In 1995, physicists at Fermilab announced the discovery of the long-sought top quark, an important milestone in the understanding of the fundamental nature of matter. By the year 2000, Fermilab's Main Injector and SLAC's B Factory will greatly enhance these laboratories' research capabilities, offering the promise of a decade of challenging research at the frontiers of particle physics.

Although we can be proud of our past achievements and look forward to further advances, the budget profile presented in *Analytical Perspectives: A Budget of the United States Government, Fiscal Year 1997* raises serious concerns about the future of particle physics research in the United States. Twenty years ago, U.S. high-energy physics not only figured among world leaders but held the preeminent position among them. If budget outlays like those in *Analytical Perspectives* should come to pass, they would force a very severe further reduction in the program; by the year 2000, the U.S. would no longer be found among world leaders in the field.

As you note in your question, the Office of Management and Budget makes these funding projections:

FY1997	FY1998	FY1999	FY2000	FY2001	FY2002
$1.009	$928	$845	$760	$867	$988

However, these figures are in then-year dollars. Stating them in terms of FY1996 dollars, assuming three percent inflation per year, provides an even clearer insight into the true impact of the OMB's projections—a 35 percent decrease in funding by the year 2000:

FY1997	FY1998	FY1999	FY2000	FY2001	FY2002
$979	$875	$773	$671	$748	$827

The funding ratio between high-energy and nuclear physics programs has remained roughly constant since the termination of the SSC. Since each program is bringing on two important new facilities, there is no justification for one to gain at the other's expense. The current programs could not sustain a uniform decrease of 35 percent across the board without closing some of these new facilities.

I will limit the rest of my comments to the high-energy physics program, because I am familiar with it. The effect on the two program-dedicated high-energy national laboratories would be extremely severe. More than 70 percent of DOE's non-construction funding of high-energy physics goes to support operations at the U.S. high-energy physics laboratories. By the year 2000, the Main Injector at Fermilab and the B Factory at SLAC will be complete. They will make SLAC and Fermilab the only two world-competitive high-energy-physics facilities in the United States. Both laboratories are necessary for a healthy U.S. program. Traditionally, Fermilab's hadrons provide the highest energy, and SLAC's electron-positron machine supplies a balancing complementary physics approach. It is the complementary pursuit of particle physics by these two different methods that has brought the U.S. program so many successes in the past. With cuts like the ones projected in the *Analytical Perspectives*, it is inconceivable that both of these laboratories could survive. One of the two laboratories, SLAC or Fermilab, would have to cease operations.

In the short run, even closing laboratories would not yield the savings one might expect. DOE would have to allocate a significant fraction of the allocated funds for decommissioning the terminated facilities. Closing a laboratory costs a great deal, because local communities will not tolerate the gradual disintegration of a working laboratory into a poorly-managed hazardous waste site. My experience in closing down the SSC Laboratory gives me some insight into the matter.

In another decade, with the commissioning of the Large Hadron Collider at CERN, the high-energy frontier will move to Europe. Without a sustained, forefront program of accelerator research in our own country, it will not be possible to bring the energy frontier back to United States in the next 15 years. Unfortunately, accelerator R&D would be another casualty if the projected funding cuts were to come about. The Department of Energy would have to forego its participation in the LHC while the field experienced a significant downsizing. For U.S. high-energy physics, LHC participation offers the best opportunity in sight to advance our own capability in superconducting magnet technology, as well as in accelerator and detector R&D.

Sixty years ago, high-energy physics was born in the United States in the laboratory of E.O. Lawrence and his students, where it acquired the distinctively American stamp that it still bears today. But if budget cuts should go as far as the outlays project, we would forfeit any U.S. leadership opportunity until at least two decades into the next century. As you consider how to fund particle physics research in the years to come, I hope that you will make it possible for the U.S. to have a leadership position in high-energy physics in the future as it has done so effectively in the past.

2. What specific changes have occurred at your laboratory as a result of the implementation of the recommendations contained in the report on the Task Force on Alternative Futures for the Department of Energy Laboratories (i.e. the Galvin Report)?

Fermilab piloted and DOE has institutionalized the "Necessary and Sufficient" process to streamline the management of Environment Safety and Health at the Laboratory. Fermilab is now managing its much of its work in accordance with the external standards that the federal government, the state of Illinois, and local governments require of private companies, rather than by the cumbersome and costly system of DOE orders previously regulating ES&H. "Necessary and Sufficient" has allowed a significant reduction in the required response to Tiger Team findings at the Laboratory, without compromising safety or the environment. While the savings are small, the cost avoidance is considerable.

DOE has piloted and is now institutionalizing the Business Management Oversight Process. The thrust of this initiative is to change from an audit to a performance-based review and evaluation system, with audits done only on a 'for cause' basis.

The number of letters from DOE requiring Laboratory action has dropped from 600 to less than 300 annually, and continues to decrease. The number of DOE orders implemented at Fermilab has fallen from 140 to about 40 and is still going down. For example, the orders regulating real property management and project management at the Laboratory have dropped from 13 to 1.

Fermilab has experienced a drop in the amount of paperwork and reporting required by DOE in several areas. While we have not yet realized significant financial savings as a result, we are able to place more of our efforts on carrying out our mission without neglecting environment, safety and health. The revolution in DOE management of the national labs initiated by the Galvin report has not yet arrived, but it does appear to have made a promising start.

3. What is the number of FTEs at your laboratory? How does this compare with your FY1995 level, and what are your outyear projections?

FY1995	**FY1996**	**FY1997**	**FY1998**	**FY1999**
2,096 (2,160*)	2,090 (2,186*)	2,020	1,945	1,870

*includes co-op students, on-call and contract workers

The number of employees has steadily declined from the nearly 2,400 employed by Fermilab in FY1991.

4. From your perspective, what impact, if any, has the DOE Laboratory Operations Board had on the operation of your laboratory, or on DOE in general?

The Laboratory Operations Board has concentrated on the multiprogram laboratories and on DOE's internal operations. Thus, the effect on a program-dedicated laboratory like Fermilab has come indirectly, through the Board's efforts to streamline DOE.

5. If the DOE FY1997 is enacted as proposed, what would be the impact on your laboratory's scientific user facilities? Would you be able to continue the same level of operation as in FY1996, or less? What additional funding, if any, would be required to maintain FY1996 operating levels?

If Congress enacts the Administration's budget request for FY1997, Fermilab will be able to operate the Tevatron, and the nine fixed target experiments that use its proton beams, for 32 weeks, as planned. This fixed-target physics run is vital to the nearly 500 physicists in these nine collaborations, since they have spent the last five years rebuilding their detectors and preparing for this run. In addition, the running period will be the last opportunity for these experiments to take data, because the Tevatron fixed-target program will be terminated after February 1998. We must take this step in order to reduce operating costs. The Laboratory is committed to operating the Tevatron in FY1997 at the same level as it did in FY1996, although we will have to delay future projects in order to operate for 32 weeks.

The rebuilding of Fermilab's two large collider detectors will continue, although at a less than desirable pace. When the rebuilding is complete, it will make possible the detection of the rare, but interesting products of proton-antiprotons collisions in the Tevatron, such as top quarks, at more than 10 times the rate achieved in 1995. Once it has reached its design goals, the Main Injector will increase the rate of collisions in the Tevatron. If the 1997 budget request is enacted, Main Injector construction will continue on schedule for completion in 1999, although the two collider detectors will not be ready until 2000.

The Laboratory will begin the R&D and conceptual design on its only new initiative, "Neutrinos at the Main Injector," (NuMI). NuMI would use the proton energy and intensity of the Main Injector to provide an intense neutrino beam aimed toward a detector 780 kilometers northwest of Fermilab in an existing underground laboratory in an iron mine in Soudan, Minnesota. The beam and detector would address in a new and unique way the question whether some neutrinos have mass.

Fermilab will also continue to strengthen its superconducting magnet R&D program, to recover from the disarray in that area of technology development following the demise of the SSC.

An additional five percent increase in Fermilab funding for FY1997 would allow the Laboratory to cover the increased power costs incurred by fixed-target physics operations without a further staff reduction. It would put the collider detector rebuilding programs on a schedule to match the completion of the Main Injector, and it would allow completion of the R&D and conceptual design work for the NuMI detectors in 1998.

6. What is the current number of foreign scientists and engineers, by nationality, conducting research at your university?

Argentina	4
Brazil	33
Canada	15
Colombia	9
England	15
France	14
Germany	25
Greece	9

India	25
Israel	13
Italy	229
Japan	128
Mexico	25
Peoples Rep. of China	12
Poland	5
Puerto Rico	6
Russia	167
South Korea	15
Switzerland	1
Taiwan	18
Turkey	1

RESPONSE TO QUESTIONS SUBMITTED BY
THE U.S. HOUSE OF REPRESENTATIVES
THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
on
The Department of Energy's FY1997 Budget Request for the Office of Energy Research

BURTON RICHTER, DIRECTOR
STANFORD LINEAR ACCELERATOR CENTER

June 21, 1996

Question One: What are the implications of the Clinton Administration's outyear figures that dip as low as $781 million in FY2000 for both the Domestic High Energy and Nuclear Physics programs and for the potential U.S. participation in the construction and operation of the LHC at CERN?

Answer: If such cuts were to occur and the High Energy and Nuclear Physics programs shared in them in strict proportion, available funding for high energy physics would decrease by 22% in nominal terms, and about 30% in real terms including the effects of inflation. Such a cut occurring over a period of three years would have a devastating impact on the laboratories and the university user community, and would require massive cutbacks in operations and personnel. It is not likely that the program as now foreseen, including operation of new facilities at SLAC and Fermilab and participation at the LHC, could be carried out effectively. The impact on science and personnel would be extraordinarily severe.

Question Two: What specific changes have occurred at your laboratory as a result of the implementation of the recommendations contained in the report of the Task Force on Alternative Future for the Department of Energy Laboratories (i.e., the Galvin report)?

Answer: The main impact of the Galvin report on us has come from the DOE's response to the Task Force's recommendation for less micromanagement, more performance-based oversight, and streamlined and simplified regulation. These have allowed us to shift resources from administration to program.

Question Three: What is the current number of FTE's at your laboratory, how does this compare with your FY1995 level, and what are your outyear projections?

Answer: Present FTE's are 1560. FY1995 average FTE's were 1637. Outyear projections are very difficult. The B-Factory Project is currently at its peak employment and expects to reduce by about 60 FTE's next year. Funding for the on-going program will determine the base laboratory staffing. At the President's proposed budget we expect that we will have to decrease staffing by an additional 50 to 100 FTE's.

Question Four: From your perspective, what impact, if any, has the DOE Laboratory Operating Board had on the operations of your laboratory, or on DOE in general?

Answer: The Laboratory Operating Board has focused mostly on the internal operations of DOE and on the multiprogram laboratories. Thus, the impact on SLAC comes primarily through the Operating Board's impact on DOE streamlining. The effect on SLAC is outlined in the answer to Question Two above.

Question Five: If the DOE FY1997 request is enacted as proposed, what would be the impact on your laboratory's scientific user facilities? Would you be able to continue the same level of operation as in FY1996, or less? What additional funding, if any, would be required to maintain FY1996 operating levels?

Answer: At the proposed budget level, funding for the operation of our user facilities will be approximately $3.5 million short of funding required to maintain FY1996 levels of operation.

Question Six: What is the current number of foreign scientists and engineers, by nationality, conducting research at your laboratory?

Answer: There are roughly 500 foreign users of our high energy physics and synchrotron radiation facilities out of 1800 total users. About half of the foreigners are involved in preparing the apparatus for the B-Factory facility now under construction and are bringing equipment valued at $35-40 million. The breakdown by country is as follows:

Italy	118	China	19
France	84	Sweden	18
United Kingdom	70	Australia	11
Russia	40	Switzerland	8
Canada	39	Austria	7
Germany	37	Isreal	5
Japan	20	Miscellaneous*	13

*From eight different countries.

BROOKHAVEN NATIONAL LABORATORY
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Office of the Director

June 25, 1996

The Honorable Dana Rohrabacher
Chairman
Energy & Environment Subcommittee
U.S. House of Representatives
Committee on Science
Suite 2320 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Rohrabacher,

I was pleased to have the opportunity to participate in the hearings of your Subcommittee on the Department of Energy's FY1997 budget request on May 8, 1996. This letter contains my additional comments, which are in answer to the seven follow-up questions.

Response to questions 1 and 2. The major dips in funding in both the High Energy and Nuclear Physics and in the general Office of Energy Research accounts such as Basic Energy Sciences represent serious blows to the United States science programs. These cuts will impair our ability to maintain a world class effort in these areas. It would not only result in the termination of many excellent programs but would send a negative signal to the bright students who we count on for the next generation of scientists.

Response to question 3. Our laboratory has instituted many programs to streamline our processes for getting research done. We have a ratio of direct research workers to support research workers of about 2.0. The process to reduce inefficiencies is a constant struggle which we must and will continue.

Response to question 4. We have 3186 FTEs now and had 3360 FTEs in FY1995.

Response to question 5. The Laboratory Operating Board is in its early stages of implementation. It will help the DOE focus on the missions and capabilities of the various National Laboratories. The Mission Plan was an important first step in that direction.

Response to question 6. We support the DOE's FY 1997 proposed budget. Overall we can maintain a reasonable user program within the constraints of that budget for the High Flux Beam Reactor and the National Synchrotron Light Source. The Alternating Gradient Synchrotron, which is used in the High Energy and Nuclear Physics Programs will be under utilized. More funding is needed in order to meet the demand of the ongoing experiments.

Response to question 7. The vast majority of the scientists, both at our lab and in our user community are United States citizens. Science is however an international enterprise. Our facilities are open to all successfully peer reviewed proposals as are the foreign facilities. That has been the tradition in science for at least the last fifty years.

Sincerely yours,

N.P. Samios

N. P. Samios
Director

HEARING OF THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

on

The Department of Energy's FY 1997 Budget Request for the Office of Energy Research

Wednesday, May 8, 1996

Followup Questions Submitted to

Dr. Nicholas P. Samios, Director, Brookhaven National Laboratory

1. Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) shows the following budget outlay profile for the DOE General Science and Research programs (i.e., High Energy and Nuclear Physics): FY 1996 = $978 million; FY 1997 = $1.002 billion; FY 1998 = $948 million; FY 1999=$865 million; FY 2000 = $781 million; FY 2001 = $840 million; and FY 2002 = $959 million.

   What are the implications of these outyear figures, which dip at low as $781 million in FY 2000, for both the domestic high energy and nuclear physics programs, and for the potential U.S. participation in the construction and operation of the Large Hadron Collider (LHC) at CERN?

2. Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) also shows the following budget outlay profile for the DOE Energy Supply R&D programs: FY 1996 = $3.907 billion; FY 1997 = $3.587 billion; FY 1998 = $3.504 billion; FY 1999=$3.385 billion; FY 2000 = $3.214 billion; FY 2001 = $3.098 billion; and FY 2002 = $3.283 billion.

   What are the implications of these outyear figures, which dip at low as $3.098 billion in FY 2000, for OER programs–such as Basic Energy Sciences–in this account?

3. What specific changes have occurred at your laboratory as a result of the implementation of the recommendations contained in the report of the Task Force on Alternative Futures for the Department of Energy Laboratories (i.e., the Galvin report)?

4. What is the current number of FTEs at your laboratory, how does this compare with your FY 1995 level, and what are your outyear projections?

5. From your perspective, what impact, if any, has the DOE Laboratory Operating Board had on the operation of your laboratory, or on DOE in general?

6. If the DOE FY 1997 is enacted as proposed, what would be the impact on your laboratory's scientific user facilities? Would you be able to continue the same level of operation as in FY 1996, or less? What additional funding, if any, would be required to maintain FY 1996 operating levels?

7. What is the current number of foreign scientists and engineers, by nationality, conducting research at your laboratory?

THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

Jefferson Lab

June 25, 1996

The Honorable Dana Rohrabacher
Chairman, Energy & Environment Subcommittee
U. S. House of Representatives
Committee on Science
Suite 2320 Rayburn House Office Building
Washington, DC 20515-6301

Dear Representative Rohrabacher:

It was a great pleasure testifying before your committee and I would like to thank you for your support and your considerations.

I have enclosed the answers to the questions from your committee as you requested in your letter of June 19, 1996.

If there is anything else I could do, please don't hesitate to ask.

Sincerely,

H. Grunder

Hermann A. Grunder
Director

Enclosure

Response to Follow Up Questions from the
Hearing of the Subcommittee on Energy and Environment
Committee on Science–May 8, 1996
House of Representatives

by

Hermann A. Grunder, Director
Continuous Electron Beam Accelerator Facility (CEBAF)

1. **Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) shows the following budget outlay profile for the DOE General Science and Research programs (i.e., High Energy and Nuclear Physics): FY 1996 = $978 million; FY 1997 = $1,002 billion; FY 1998 = $948 million; FY 1999 = $865 million; FY 2000 = $781 million; FY 2001 = $840 million; and FY 2002 = $959 million.**

   What are the implications of these outyear figures, which dip as low as $781 million in FY 2000, for both the domestic high energy and nuclear physics programs and for the potential U. S. participation in the construction and operation of the Large Hadron Collider (LHC) at CERN?

   The General Science budget line currently supports four major domestic facilities (FNAL, SLAC, CEBAF, and RHIC) and one international initiative (LHC), along with experimental and theoretical research. These facilities provide world-leading, complementary capabilities for advancing fundamental science. Each facility is either new or newly upgraded. Funded at $1 billion, the General Science program is 10%-15% below the level required for full and effective use of these facilities. Sacrifices are being made in a number of areas.

   The projection for FY 2000 of $781 million represents a 30% cut in buying power from the FY 1996 funding. The only way such a cut could be accommodated is by closing two facilities and terminating many of the groups conducting research. The U.S. has made considerable investment in these facilities, and General Science in the U.S. would be narrowed and impoverished by their untimely loss.

   The budget increases projected for the years FY 2001 and FY 2002 would provide welcome and necessary relief for the remaining facilities, and allow their programs to be optimized.

2. **What specific changes have occurred at your laboratory as a result of the implementation of the recommendations contained in the report of the Task Force on Alternative Futures for the Department of Energy Laboratories (i.e., the Galvin report)?**

   In October 1995, CEBAF began operating under a new performance-based contract, which includes many of the private sector cost-saving principles recommended by the Galvin report. We are achieving a cost saving of $2 million in FY 1996 (out of a total annual budget of about $70 million). A total annual savings of $4 million in FY 1997 and future years is assumed in the President's Budget Request for FY 1997, based on full implementation of the performance-based contract.

   Thus far we have implemented initiatives to streamline procurement, and we are negotiating with DOE to allow us to implement personnel practices conforming with best business practice. We are also working with DOE to reduce excessive numbers of reviews and audits. Employees at all levels are involved in targeting and pursuing numerous cost reductions and efficiency improvements in their work groups.

3. **What is the current number of FTEs at your laboratory, how does this compare with your FY 1995 level, and what are your outyear projections?**

The following are current and projected staffing levels at the Continuous Electron Beam Accelerator Facility:

	FISCAL YEAR			
	1995*	1996	1997	1998-2002
CEBAF Staffing	562	527	424	424

*Final year of construction

4. **From your perspective, what impact, if any, has the DOE Laboratory Operating Board had on the operation of your laboratory, or on DOE in general?**

The existence of the Laboratory Operating Board strengthens DOE's resolve to follow through on the Galvin recommendations. The Continuous Electron Beam Accelerator Facility, as a new and program dedicated laboratory has had no significant interactions with the Laboratory Operating Board.

5. **If the DOE FY 1997 is enacted as proposed, what would be the impact on your laboratory's scientific user facilities? Would you be able to continue the same level of operation as in FY 1996, or less? What additional funding, if any, would be required to maintain FY 1996 operating levels?**

Utilization of existing facilities to increase scientific output is the highest priority in nuclear physics as recommended by the Nuclear Science Advisory Committee. The 1997 President's Budget allows the Continuous Electron Beam Accelerator Facility to run at the same level as in FY 1996 (30 weeks).

6. **What is the current number of foreign scientists and engineers, by nationality, conducting research at your laboratory?**

CEBAF's user community consists of about 1100 users, 174 of whom are foreign participants on approved experiments. CEBAF's international users have made significant financial and manpower contributions to building the detectors in the experimental halls.

Country/Nationality	Number of Participating Scientists/Engineers
France	45
Italy	33
Armenia	27
Russia	15
Switzerland	10
Canada	9
The Netherlands	6
Other Countries	29
TOTAL	174

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439-4832

June 28, 1996
via Fax: 202/225-0145

The Honorable Dana Rohrabacher
Chairman, Energy & Environment Subcommittee
Committee on Science
U.S. House of Representatives
Suite 2320 Rayburn House Office Bldg.
Washington, D.C. 20515-6301

Dear Representative Rohrabacher:

Reference: Your letter of June 17 to D. Moncton of Argonne, with questions following up on the May 8 hearings regarding the FY 1997 budget request from the Department of Energy for the Office of Energy Research

Following are the responses of Argonne National Laboratory to the questions posed in the referenced letter. Please contact me if we can provide any further information.

Sincerely,

Alan Schriesheim
Director

c: D. Moncton

1. **Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) shows the following budget outlay profile for the DOE General Science and Research programs (i.e., High Energy and Nuclear Physics): FY 1996 = $978 million; FY 1997 = $1.002 billion; FY 1998 = $948 million; FY 1999 = $865 million; FY 2000 = $781 million; FY 2001 = $840 million; and FY 2002 = $959 million.**

   What are the implications of these outyear figures, which dip as low as $781 million in FY 2000, for both the domestic high energy and nuclear physics programs, and for the potential U.S. participation in the construction and operation of the Large Hadron Collider (LHC) at CERN?

   Funding for U.S. participation in the Large Hadron Collider (LHC) at CERN for FY 1998 - FY 2002 has been proposed at $50 million per year. Using FY 1997 as a base of comparison, this level of funding implies cuts in the domestic high energy and nuclear physics programs as great as 25% in nominal dollars, even more when inflation is taken into account. The necessary reallocation of resources would require either closing the Stanford Linear Accelerator (SLAC) or eliminating all support for research at universities. Either of these scenarios would greatly damage the domestic U.S. high energy and nuclear physics programs and would be unacceptable to Argonne.

2. **Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) also shows the following budget outlay profile for the DOE Energy Supply R&D programs: FY 1996 = $3.907 billion; FY 1997 = $3.587 billion; FY 1998 = $3.504 billion; FY 1999 = $3.385 billion; FY 2000 = $3.214 billion; FY 2001 = $3.098 billion; and FY 2002 = $3.283 billion.**

   What are the implications of these outyear figures, which dip as low as $3.098 billion in FY 2000, for OER programs — such as Basic Energy Sciences — in this account?

   As measured in nominal, or then-year dollars, the FY 2002 budget for DOE Energy Supply R&D programs would be 16% below the budget for FY 1996. If inflation over this period were to average 3.0 percent per year, the real reduction would amount to 30 percent. We do not know how reductions would be allocated among the Energy Supply R&D programs. However, if Basic Energy Sciences shared percentage reductions in the range of 16-30%, the effects on BES programs would be catastrophic, probably entailing the closing down of several national user facilities for synchrotron and neutron science.

3. **What specific changes have occurred at your laboratory as a result of the implementation of the recommendations contained in the report of the Task Force on Alternative Futures for the Department of Energy Laboratories (i.e., the Galvin report)?**

To date, the most significant changes related to the Galvin Task Force report that have begun at Argonne address issues of laboratory governance, particularly the recommendations in Appendix B of the report. Below we discuss DOE initiatives to (1) reform and reduce DOE orders, (2) transition to external regulation, (3) consolidate and simplify DOE audits and appraisals, and (4) reform procurement practices.

Reform and Reduce DOE Orders - The University of Chicago's contract with DOE to operate Argonne National Laboratory includes a section (Appendix I) that enumerates the DOE orders applicable to the Laboratory. At the time the latest contract was signed, in June 1995, 133 orders were specified. As of June 1996, 76 orders had been cancelled and 19 new orders issued, resulting in a net reduction to 76 orders now enumerated as applicable. This reduced number reflects consolidations, clarifications, removal of redundancies, and elimination of prescriptiveness. The great majority of the revised orders continue to impose the same requirements that existed prior to the revision. However, one outstanding example of order revision that serves as a model for meeting the spirit and intent of the Galvin report is the Life-Cycle Asset Management (LCAM) order (DOE 430.1), which was authorized by DOE for implementation by Argonne in March 1996. The LCAM order has fundamentally modified certain key requirements from 13 old DOE orders, giving contractors flexibility in applying best business practices. Argonne estimates it will be able to achieve cost avoidance of about $15 million over the next five years as a result.

A DOE initiative to reduce the environment, safety, and health (ES&H) work requirements embodied in DOE orders is the “Necessary and Sufficient” process, now renamed “Work Smart Standards.” This process allows projects or entire laboratories to do fundamental assessments of hazards, and (within the constraints of legal requirements) to select the most appropriate safety regulations, without being constrained by the established DOE order system. Argonne has been instrumental in defining a rigorous process for this reform, and has successfully completed one of nine DOE pilot projects. As a consequence, the Laboratory's prime contract has been modified. For the completed pilot project, only those ES&H requirements deemed necessary have been substituted for the full set of ES&H orders included in Appendix I of the original prime contract.

Transition to External Regulation - Argonne has strongly supported transition of the Laboratory to external regulation. Argonne was selected as a site for a DOE pilot program wherein OSHA would act as the Laboratory's safety and health regulator for a six-month period. This pilot is based on OSHA's “Partnership in Excellence Program” (PEP), as part of which OSHA will determine whether Argonne's safety programs and work processes qualify it for self-regulation. If designated a PEP partner, the Laboratory would be expected to maintain a superior safety program, and OSHA's involvement at the site would be limited to investigating serious accidents and responding to significant employee concerns. The pilot project began in June 1996 and will conclude at the end of CY 1996.

Consolidate and Simplify DOE Audits and Appraisals - In October 1995 DOE instituted a Business Management Oversight Pilot program at Argonne. This pilot required DOE to consolidate all its administrative and business audits and appraisals (except for ES&H and Safeguards & Security) into a two-week period; the past practice of various DOE offices had been to conduct numerous uncoordinated evaluations during each year. The outcome of the Argonne pilot in October 1995 was viewed as a success by all parties. DOE found acceptable all systems reviewed, and administrative and business appraisals have been essentially eliminated during the ensuing period. DOE institutionalized the Business Management Oversight process in May 1996, and the Laboratory expects continuing suspension of interim audits and appraisals.

Reform Procurement Practices - DOE has launched an aggressive initiative to reform procurement practices throughout the Department and has thereby opened many opportunities for improvements at Argonne. The Laboratory has already implemented a number of good business practices. More have begun or are being planned. A revised Argonne Procurement Manual, incorporating these best business practices, is being prepared.

In collaboration with the other DOE Energy Research (ER) laboratories, Argonne has identified major barriers to further procurement reform. A study of the issue was delivered to DOE in April 1996, and DOE is now working with its laboratories to investigate further opportunities for reform.

4. **What is the current number of FTEs at your laboratory, how does this compare with your FY 1995 level, and what are your outyear projections?**

Unlike an employee head count on a particular date, FTEs are a budget-related concept applying to an entire year. Argonne's estimate for FY 1996 is still partly a projection, but it should be reasonably accurate: 4930. The historical FTE figure for FY 1995 is 4990.

It is important to understand the philosophical bases for Argonne's outyear projections. The projection for FY 1997 is generally consistent with the President's budget proposal for that year: 4720.

Projections for FY 1998 reflect preliminary guidance from the Department of Energy; no specific DOE guidance for FY 1999-FY 2002 has yet been provided. These later outyear projections do not necessarily represent outcomes that the Laboratory considers most likely. Rather, they represent a desirable future for Argonne in an environment that nevertheless is recognized as constrained by federal budgetary stringency. Such outyear projections serve as a planning baseline that the Laboratory is both prepared to undertake and prepared to depart from as contingencies require: FY 1998, 4740; FY 1999, 4730; FY 2000, 4730; FY 2001, 4720; and FY 2002, 4720.

5. **From your perspective, what impact, if any, has the DOE Laboratory Operations Board had on the operation of your laboratory, or on DOE in general?**

Creation of the Laboratory Operations Board was motivated in part by the Galvin Task Force report. Among its most important advisory responsibilities are the laboratory governance reforms discussed in response to question 3 above. Like effects from the Galvin Task Force report, effects from the Laboratory Operations Board are not easy to disentangle from the impacts of broader Departmental initiatives.

The most concrete product to date from the Laboratory Operations Board is the *Strategic Laboratory Missions Plan*, which is about to be issued in final form. Argonne has great hope that this document will help to correct misunderstandings about how DOE chooses the most effective performers — including universities, private industry, and multiprogram laboratories — for its R&D programs.

6. **If the DOE budget for FY 1997 is enacted as proposed, what would be the impact on your laboratory's scientific user facilities? Would you be able to continue the same level of operation as in FY 1996, or less? What additional funding, if any, would be required to maintain FY 1996 operating levels?**

If the President's FY 1997 budget request is enacted as proposed, we anticipate that operations of the Argonne Tandem-Linac Accelerator System (ATLAS), the Intense Pulsed Neutron Source (IPNS), and the High-Voltage Electron Microscope—Tandem Accelerator Facility will continue at about the same level as in FY 1996.

The budget request for the Advanced Photon Source (APS) provides $13.9 million less than the level that had long been planned for full operation of the facility in FY 1997. This reduction significantly increases the risk of poor and limited use of this major new U.S. facility. Research crucial to implementing a highly reliable and optimized facility will have to be postponed. Also, the operating schedule will have to be restricted, thereby delaying APS user research programs and yielding competitive advantage to users of the just-completed European Synchrotron Radiation Facility and the Japanese SPring-8 facility that is to be completed next year.

7. **What is the current number of foreign scientists and engineers, by nationality, conducting research at your laboratory?**

In June 1996, Argonne has 435 scientists and engineers with non-U.S. citizenship in paid status as researchers at the Laboratory. In addition, there are 149 foreign researchers in no-pay status. Breakdowns by country of citizenship are as follows:

Non-U.S. Paid

Algeria	3	India	48	Poland	11
Argentina	3	Indonesia	1	Portugal	1
Australia	5	Iran	3	Russian Fed.	29
Austria	2	Ireland	1	S. Korea	9
Bangladesh	2	Israel	9	Singapore	1
Belgium	4	Italy	10	S. Africa	2
Brazil	5	Japan	7	Spain	1
Canada	20	Jordan	1	Sri Lanka	1
China	79	Lebanon	2	Sweden	2
Colombia	3	Malaysia	3	Switzerland	2
Costa Rica	3	Mauritania	1	Syria	1
Denmark	3	Mexico	5	Taiwan	29
Egypt	3	Morocco	1	Thailand	2
France	6	Netherlands	1	Tunisia	1
Germany	35	New Zealand	2	Turkey	5
Ghana	1	Nigeria	3	U.K.	31
Greece	6	Paraguay	1	Venezuela	1
Hong Kong	7	Peru	2	Viet Nam	1
Hungary	5	Philippines	3	Yugoslavia	6
				TOTAL	435

Non-U.S. No-Pay

Algeria	1	Finland	2	Malaysia	1
Argentina	3	France	6	Mexico	1
Australia	2	Germany	13	Morocco	1
Austria	2	Greece	1	New Zealand	1
Bangladesh	1	Hong Kong	1	Pakistan	1
Belgium	2	Hungary	1	Poland	7
Brazil	3	India	9	Russian Fed.	8
Bulgaria	1	Iran	1	Sweden	1
Cambodia	1	Ireland	1	Switzerland	1
Canada	2	Italy	7	Taiwan	5
China	23	Japan	14	U.K.	19
Colombia	1	Jordan	1	Yugoslavia	2
Croatia	1	Lebanon	1		
				TOTAL	149

Response to Follow-up Questions by

Alvin W. Trivelpiece
Director, Oak Ridge National Laboratory

from the

Hearing of the Subcommittee on Energy and Environment
Committee on Science
U. S. House of Representatives

on

The Department of Energy's FY 1997 Budget Request
for the Office of Energy Research
May 8, 1996

Question 1

Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) shows the following budget outlay profile for the DOE General Science and Research programs (i.e. High Energy and Nuclear Physics): FY 1996 = $978 million; FY 1997 = $1.002 billion; FY 1998 = $948 million; FY 1999 = $865 million; FY 2000 = $781 million; FY 2001 = $840 million; and FY 2002 = $959 million.

What are the implications of these outyear figures, which dip as low as $781 million in FY 2000, for both the domestic high energy and nuclear physics programs, and for the potential U.S. participation in the construction and operation of the Large Hadron Collider (LHC) at CERN?

Response to Question 1

The DOE's General Science program is the major source of support for this country's fundamental research programs in High Energy and Nuclear Physics. At present, DOE supports about 80 percent of the U.S. effort in this area (about 3500 experimenters and 1500 theorists), in work that has garnered much recognition (including 19 Nobel Prizes) since the end of World War II.

The implications of the outyear figures shown for this program are that its present level of excellence will be irreparably damaged. Both research communities (High Energy Physics and Nuclear Physics) have worked hard to develop long-range plans that will maintain program excellence under the condition of constrained budgets. The implementation of these plans would be impossible, however, with the draconian reductions now shown in the outyear figures.

An example of the impact of such extreme program reductions can be obtained by examining the effect on the Nuclear Physics program. In the near term, this program can be subdivided into three, nearly equal, components: two being the major accelerator facilities and their associated research, and the other all the remaining program research at universities and smaller facilities. The two major facilities are the newly completed Continuous Electron Beam Accelerator (CEBAF) at the Thomas Jefferson Laboratory and the nearly complete Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. Both facilities represent world-unique opportunities for fundamental and applied research well into the next century. The effect of the outyear figures on this program (assuming that the reductions are prorated equally between High Energy and Nuclear Physics) would be that one of these three program components would have to be eliminated. Thus, one of the major new research facilities (CEBAF or RHIC) would be abandoned, or the remainder of the research program, located at universities and smaller facilities (largely support of scientists and students) would be eliminated. Any of the options would devastate the program and destroy the world-class excellence for which it is noted.

A very similar argument can be made for the High Energy Physics program, with much the same final conclusion. Under these conditions, it seems highly unlikely that potential U.S. participation in construction and operation of the LHC at CERN would be viewed with much favor.

Question 2

Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) also shows the following budget outlay profile for the DOE Energy Supply R&D programs: FY 1996 = $3.907 billion; FY 1997 = $3.587 billion; FY 1998 = $3.504 billion; FY 1999 = $3.385 billion; FY 2000 = $3.214 billion; FY 2001 = $3.098 billion; and FY 2002 = $3.283 billion.

What are the implications of these outyear figures, which dip as low as $3.098 billion in FY 2000, for the OER programs - such as Basic Energy Sciences - in this account?

Response to Question 2

Cuts of this magnitude in the OER programs, such as Basic Energy Sciences, would be detrimental to the continued effectiveness of our Nation's science and technology enterprise. The OER forms a unique foundation for basic science in the U.S., directly supporting a broad spectrum of science at universities and in industry as well as the DOE National Laboratories. The user facilities in the OER alone support thousands of researchers each year to perform basic and applied investigations and product development that cannot be performed elsewhere because the facilities are unique.

Basic science, unlike goal-directed project work, manufacturing, or product development, demands sustained and learned participation to achieve new breakthroughs and to sustain user interactions. Declining funds of the magnitude shown would result in permanent loss of some areas of expertise that could not be rebuilt on short notice.

Question 3

What specific changes have occurred at your laboratory as a result of the implementation of the recommendations contained in the report of the Task Force on Alternative Futures for the Department of Energy (DOE) Laboratories (i.e.. the Galvin Report)?

Response to Question 3

The short answer is that ORNL is very pleased with the focused approach for the examination of the Department's national laboratories that began with the Galvin Task Force. There was an adequate opportunity to interact with the Galvin Task Force as it members formulated their report; we submitted written information for their consideration, provided personal testimony at several meetings, and interacted with them during their site visits. DOE has taken the recommendations seriously and has developed responses that will prove beneficial to the way the national laboratories do business. Two other groups were formed in this same spirit: the Task Force on Strategic Energy Research and Development (that developed the Yergin Report) and the Advisory Committee on External Regulations of Department of Energy Nuclear Safety (that developed the Ahearne Report). The Department of Energy Laboratory Operations Board was formed with external members that will provide continuity and improved operation for the national laboratories.

What is more important is that the attitude of Galvin extends beyond DOE into the activities of management and operating contractors. This has been particularly evident in the recent evolution of the contract for Oak Ridge National Laboratory. Lockheed Martin Corporation was created in 1995 with the merger of Lockheed and Martin Marietta. In determining the structure of the new organization, the Energy and Environment Sector was created in August 1995 to bring together those organizations managed for DOE under the leadership of Al Narath, the President of the Sector. The contract of Lockheed Martin Energy Systems (Energy Systems), the DOE contractor for ORNL and two other sites in Oak Ridge, was extended for two years on August 30, 1996. Soon afterward, a clause in that contract was exercised by DOE to establish a separate contract with Lockheed Martin for the management of ORNL. The Lockheed Martin Energy Research Corporation was formed in October 1995 [illegible] contract was signed with DOE on December 6, 1995, for the management of ORNL. Operations commenced under the new contract on January 1, 1996.

What brought about this change in management of ORNL? I believe it began with the Galvin Task Force and their examination of how the national laboratories could be more effective and efficient. Certain conditions and management practices of Energy Systems were not regarded as optimal for the research and development activities of a national laboratory. Also, the President of Lockheed Martin's Energy and Environment Sector felt that all of the national laboratories under his purview -- ORNL, Sandia National Laboratories, and Idaho National Engineering Laboratory -- should have the similar status of reporting directly to him.

Certain Recommendations summarized in Appendix B of the Galvin Task Force report, were made to correct practices and policies. Many changes have resulted from the Environment, Safety, and Health Pilot and Business Management Oversight Pilot programs. ORNL has seen a reduction in the number of audits and reviews. The Necessary and Sufficient process, which is based on industry-wide regulatory standards of focusing attention where there is risk, shows great promise for reducing indirect costs.

We are not yet where we should be. If the number of DOE and contractor personnel is to decline as anticipated, work also needs to be taken out of the system. I don't believe DOE or the contractors have fully completed analyses of which activities are really necessary. At ORNL, we engaged the services of Ernst & Young LLP to assist us in reengineering. This effort began 10 months ago to identify the service and support functions that ORNL obtained from Energy Systems. We are making decisions now concerning which functions will be outsourced to contractors other than Energy Systems, which Energy Systems staff should transfer to ORNL to perform their functions, and which activities should be eliminated. We expect these decisions to be made prior to the beginning of FY 1997.

Question 4

What is the current number of FTEs at your laboratory, how does this compare with your FY 1995 level, and what are your outyear projections?

Response to Question 4

During recent years, Oak Ridge National Laboratory has had about 5,000 employees reporting to its director. Of this number, 1,500 are scientists and engineers. We also have over 4,000 guest scientists and engineers from academic and industrial institutions, who are estimated to be the full-time equivalent of 1,500 staff, giving us a total of about 3,000 researchers.

At the end of FY 1995, the number of employees of Oak Ridge National Laboratory was 4,369. As of May 31, 1996, this level was 4,428. Out-year projections are difficult given the uncertainty of funding. Projected employment for year-end FY 1997 is 4,350, and the level projected for year-end FY 1998 is 4,300. ORNL procures services from other organizations including Energy Systems for temporary needs, economies of scale, or special expertise. These employment figures are exclusive of those personnel. Studies are under way to determine the most appropriate structure for the organizational placement of procured personnel to attain the highest efficiency and cost-effectiveness of operation.

Question 5

From your perspective, what impact, if any, has the DOE Laboratory Operating Board had on the operation of your laboratory, or on DOE in general?

Response to Question 5

The Laboratory Operations Board has not been in business a long time. It was established by the Secretary O'Leary on April 11, 1995, to provide regular attention to issues facing DOE's national laboratory system. Roles and responsibilities that were assigned to the Board include helping provide strategic direction for the DOE laboratories, monitoring the implementation of management improvement and cost-cutting initiatives, and enhancing coordination among the laboratories. The Board consists of 16 members; eight are senior officials from the Department, and eight are representatives from the private sector, academia, or the public. I believe that formation of this group was partly inspired by the Galvin Report, particularly Appendix B, which focused on reforms needed to correct the present system.

I believe this Board is a useful vehicle to maintain a recognition of the value of the Department's laboratories from one administration to another.

On September 7, 1995, during testimony before the House Science Committee, Deputy Secretary of Energy Charles Curtis described the purpose of the external members of the Laboratory Operations Board in the following way:

"Their role is to serve as a conscience and an insistent set of advisors that will keep the Department focused on the challenge of creating a more productive, mission focused, and cost-effective Department and laboratory system. They will help ensure that the Galvin Task Force report will not suffer the fate of many previous examinations of DOE laboratories."

First, both the character and specificity of reforms undertaken by the Department and its laboratories are more serious and far-reaching than has been seen in response to prior examinations of the Department's laboratories. And second, the extent to which the Department is starting to institutionalize these reforms is unlike anything that we have observed in the past.

Establishment of the Laboratory Operations Board is a prime example of the Department's efforts to ensure enduring change in the way the Department manages its laboratories. Never before has the Department created an oversight body--including external members--for the purpose of holding the Department and its laboratories accountable to their commitments to cut costs, enhance R&D productivity, and curb unnecessary and counterproductive management burdens at the laboratories. The board's role is to help the Department and its laboratories meet the ambitious goals that have been set in these areas, and to press for additional reforms as well.

Question 6

If the DOE FY 1997 (budget) is enacted as proposed, what would be the impact on your laboratory's scientific user facilities? Would you be able to continue the same level of operation as in FY 1996, or less? What additional funding, if any, would be required to maintain FY 1996 operating levels?

Response to Question 6

Details of the FY 1997 budgets of user facilities proposed by DOE do not permit extensive analysis. To the best of our knowledge, the levels proposed by DOE are the same as FY 1996 with inflation. At this level, the same level of operation is anticipated for FY 1997.

For Oak Ridge National Laboratory, decreased funding in FY 1997 would result in a decrease in the level of user support. The Scientific Facilities Initiative (SFI) funds in FY 1996 were used to improve the equipment and instrumentation at some of our user facilities in order to increase user access and utilization. A decrease in funds now would result in unfinished improvements and/or reduced permanent staff to assist users. At least flat funding, adjusted for inflation and including renewal of the SFI funding, would be required to maintain FY 1996 operating levels. It should be noted that the very small SFI funds have been enormously efficient for existing user facilities, resulting in sizable increases in utilization for small incremental support.

Question 7

What is the current number of foreign scientists and engineers, by nationality, conducting research at your laboratory?

Response to Question 7

It is important for DOE's national laboratories to work closely with scientists and engineers of other countries, for many of the same reasons that national laboratory scientists find it valuable to work closely with colleagues from academic and industrial institutions. ORNL views research colleagues from academic and industrial institutions, as well as those based overseas, as providing an extension to our workforce. A highly valuable approach to scientific dialogue occurs when colleagues can interact with other on a daily basis and exchange ideas on how to approach problems that they are trying to understand. A decade ago, DOE national laboratories were directed to increase technology transfer. A key element of this proved to be increasing the number of guest researchers from universities and industry to the national laboratories. Because of these guest researchers, the scientific workforce of ORNL is effectively doubled.

The ORNL staff benefits from these interactions as they are welcomed in overseas research institutions. This is a balanced exchange, and provides a quid pro quo for access to state-of-the-art research facilities by DOE national laboratory scientists in other countries. This gives our scientists an opportunity to learn of the research agendas of their colleagues. A June 1996 report of the National Academy of Engineering, *Foreign Participation in U.S. Research and Development: Asset or Liability?,* analyzes foreign participation in U.S. R&D in detail.

The following statistics reflect all foreign scientists and engineers conducting research at Oak Ridge National Laboratory, on a full-time or part-time basis, and includes those supported by DOE as employees of ORNL, and those who are guest scientists or engineers from other industrial or academic institutions either in the United States or overseas. The 903 foreign scientists and engineers come from 73 countries.

Algeria	1
Argentina	14
Australia	15
Austria	4
Bangladesh	9
Belgium	6
Brazil	9
Bulgaria	4
Canada	34
Chile	4
Colombia	3
Croatia	1
Cyprus	2
Denmark	5
Dominican Republic	1
Egypt	2
Ethiopia	3
Finland	1
France	25
Germany	43
Germany/US	1
Germany/Venezuela	1
Ghana	2
Greece	12

Hong Kong	4
Hungary	6
India	128
Indonesia	2
Iran	5
Israel	10
Italy	13
Japan	40
Jordan	4
Kenya	2
Kyrgyzstan	1
Macedonia	1
Malaysia	3
Mexico	11
Morocco	1
Netherlands	8
New Zealand	3
New Zealand/UK	1
Nigeria	5
Pakistan	2
Peru	1
Philippines	5
Poland	14
Peoples' Republic of China	171
Romania	3
Russia	43
Serbia	1
Sierra Leone	2
Singapore	1
Slovenia	3
South Africa	1
South Korea	39
Spain	8
Sri Lanka	2
Stateless	1
Sweden	9
Switzerland	5
Syria	1
Taiwan	35
Thailand	5
Trinidad	1
Tunisia	1
Turkey	4
Ukraine	7
United Arab Emirates	1
United Kingdom	81
Venezuela	2
West Indies	1
Yugoslavia	3

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July 12, 1996

The Honorable Dana Rohrabacher
Chairman, Energy and Environment Subcommittee
Committee on Science
U. S. House of Representatives
B-374 Rayburn House Office Building
Washington, D. C. 20515

Dear Mr. Rohrabacher:

Enclosed are my responses to your June 17, 1996 questions following my appearance at your Subcommittee's May 8, 1996 hearing. I hope that this information proves useful to you, and that you will not hesitate to contact me for any additional information.

Thank you again for the opportunity to testify on the FY 1996 budget.

Sincerely,

C V Shank

Charles V. Shank
Director

Enclosure

HEARING OF THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES
on
The Department of Energy's FY 1997 Budget Request
for the Office of Energy Research
Wednesday, May 8, 1996

Follow-up Questions Submitted to
Dr. Charles V. Shank, Director, Lawrence Berkeley National Laboratory

1. Q

Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) shows the following budget outlay profile for the DOE General Science and Research programs (i.e., High Energy and Nuclear Physics): FY 1996 = $978 million; FY 1997 = $1.002 billion; FY 1998 = $948 million; FY 1999 = $865 million; FY 2000 = $781 million; FY 2001 = $840 million; and FY 2002 = $959 million.

What are the implications of these outyear figures, which dip at low as $781 million in FY 2000, for both the domestic high energy and nuclear physics programs, and for the potential U.S. participation in the construction and operation of the Large Hadron Collider (LHC) at CERN?

A

Recognizing the need to bring the Federal budget into balance, I am concerned about the continued level of support in future years for all areas of basic scientific research. The Office of Energy Research within the Department of Energy, which is the home for these programs, is a critically important part of our national scientific infrastructure, and needs to be treated equally with other research performers such as the National Institutes of Health and the National Science Foundation.

I also realize the specific funding levels in each of those years will be an outcome of the Federal budget process and negotiations between the Executive and Legislative branches. I would therefore strongly urge both branches to provide the maximum level of support possible for basic scientific research, recognizing that the fruits of this research will be a major driver of our 21st century economy.

2 Q

Page 358 of the *Analytical Perspectives* volume of the Fiscal Year 1997 *Budget of the United States Government* (H. Doc. 104-162/Vol. 3) also shows the following budget outlay profile for the DOE Energy Supply R&D programs: FY 1996 = $3.907 billion; FY 1997 = $3.587 billion; FY 1998 = $3.504 billion; FY 1999 = $3.385 billion; FY 2000 + $3.214 billion; FY 2001 = $3.098 billion; and FY 2002 = $3.283 billion.

What are the implications of these outyear figures, which dip at low as $3.098 billion in FY 2000, for OER programs-such as Basic Energy Sciences in this account?

A

My response to this question is the same as that for Question #1, especially my concern about the overall treatment of the basic research programs of DOE's Office of Energy Research. They are an important component of the nation's research investment portfolio and need to be treated as such.

3. Q

What specific changes have occurred at your laboratory as a result of the implementation of the recommendations contained in the report of the Task Force on Alternative Futures for the Department of Energy Laboratories (i.e., the Galvin report)?

A

The recommendations of the Galvin report, along with the continued pressures on the Federal budget and the "reinventing government" focus of the Administration, have all contributed to significant changes at the Berkeley Laboratory. Working in partnership with the Department of Energy, we have been able to significantly reduce and eliminate unnecessary administrative practices. This effort allowed the Laboratory to reduce its central administrative staff by 15% in FY 1995, resulting in a reduction in our overhead costs and allowing us to perform more research with every dollar coming into the laboratory.

We have also worked with the Department of Energy to streamline its oversight of the laboratory, focusing its efforts on where it can add value to the Laboratory and the University of California's oversight practices. Additionally, the Laboratory has been moving aggressively to implement administrative and financial reforms based on the best management practices employed in the private sector. I anticipate that this effort will result, over time, in further administrative efficiencies and reductions in overhead expenditures.

4. Q

What is the current number of FTEs at your laboratory, how does this compare with your FY 1995 level, and what are your outyear projections?

A

The table below has the Laboratory staffing projections from our most recent Institutional Plan. The reductions between 1995 and 1996 are attributable to programmatic reductions and the administrative efficiencies described in my answer to question #3. The increase in 1997 in and beyond can be attributed to the Laboratory's' recent assignment of the management of the National Energy Research Scientific Computing Center and the Energy Sciences network, expected growth in the use of the Advanced Light Source, and expected growth in the Human Genome Project and related biological research.

Fiscal Year	Direct	Indirect	Total FTE
1995	1794	782	2576
1996	1786	644	2430
1997	1856	668	2524
1998	1918	687	2605
1999	1926	690	2616
2000	1941	696	2636

5. Q

From your perspective, what impact, if any, has the DOE Laboratory Operating Board had on the operation of your laboratory, or on DOE in general?

A

Serving as the only Laboratory Director on the Laboratory Operating Board, I have a dual perspective on its effectiveness. For the Department as a whole, I believe that the Board has been an effective way to bring together all the senior Department management with experienced corporate R&D executives to deal with issues that affect the laboratories and their programs across the agency. For the laboratories, I believe that the Board has become a very useful place to bring up larger management issues for attention, and to insure that the external members of the Board can help the Department focus on developing its best management practices modeled after those in the private sector. I have also been struck by the important role in the deliberations of the Board played by the non-government participants. They bring a fresh, and very different, point of view to the table, and it greatly adds to the deliberations and recommendations of the board.

6. Q

If the DOE FY 1997 is enacted as proposed, what would be the impact on your laboratory's scientific user facilities? Would you be able to continue the same level of operation as in FY 1996, or less? What additional funding, if any, would be required to maintain FY 1996 operating levels?

A

The Berkeley Lab operates three scientific user facilities: the Advanced Light Source, the National Center for Electron Microscopy, and the 88-inch cyclotron. The first two are funded by the DOE Materials Science program, and the last by the Nuclear Physics program. It is my understanding that the proposed FY 1997 budget, if enacted, would result in a small (less than 1%) reduction in the budgets for these facilities. We will be working with the Department as the budget process moves forward to negotiate the most favorable operating budget for our users. Since the combined operating budgets for these three facilities is approximately $30 million, an additional $4 million added to the FY 1997 request would bring them to the buying power of their FY 1996 operating level.

7. Q

What is the current number of foreign scientists and engineers, by nationality, conducting research at your laboratory?

A

The Berkeley Lab currently employs 396 foreign nationals, which includes 186 career employees, 161 with limited term appointments, and 149 temporary employees. The countries of citizenship are Algeria (3), Argentina (6), Austria (2), Australia (9), Belgium (3), Bolivia (2), Brazil (4), Bulgaria (1), Burma (1), Canada (29), Chile (2), Denmark (3), England (3), Ethiopia (1), France (16), Germany (32), Greece, (5), Hong Kong (4), Hungary (4), Iceland (1), India (25), Indonesia (2), Iran (5), Ireland (2), Israel (9), Italy (5), Japan (14), Kenya (1), Malaysia (2), Mexico (5), North Korea (2), New Zealand (1), Netherlands (2), Norway (1), Pakistan (2), Peru (1), Philippines (1), Poland (8), Peoples Republic of

China (65), Republic of China (16), Rumania (1), Russia (16), South Africa (2), South Korea (11), Singapore (1), Spain (4), Sri Lanka (2), Sweden (2), Switzerland (7), Tanzania (1), Trinidad (1), Turkey (1), United Kingdom (39), Venezuela (2), Vietnam (3) Yugoslavia (2), and unknown (111).

July 1, 1996

The Honorable Dana Rohrabacher
Subcommittee on Energy and Environment
Committee on Science
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

In response to your request of June 17, enclosed are the answers to the questions you asked in conjunction with the hearing before your Subcommittee on May 8, 1996.

If there is additional information required, please let me know.

Sincerely,

Wm Madia

William J. Madia
Director

Attachment

WJM:mt

Phone (509) 375-6600 ■ FAX: (509) 375-6844 ■ Internet wj_madia@pnl.gov

1. Page 358 of the *Analytical Perspectives volume* of the Fiscal year 1997 *Budget of the United States Government* also shows the following budget outlay profile for the DOE Energy Supply R&D programs: FY96=$3.907B, ... FY 2002 = $3.283B.

What are the implications of these outyear figures, which dip as low as $3.098B in FY 2000, for OER programs -- such as Basic Energy Sciences -- in this account?

The level of funding shown for the Office of Energy Research over the next seven years is going to have significant impacts on the scientific user community and the research community (universities and national laboratories) that are funded by the Department of Energy's physics, chemistry, biology, environmental science, and computational science programs. As the pace of technological innovation continues to increase, scientific leadership is ever more important to our society. Scientific discoveries and their eventual translation into civilian and military technologies requires continued investment in the generation of new knowledge. The Department of Energy's research portfolio contributes significantly to the development of scientific knowledge and new technologies each year. The cited funding profile will diminish this effort and limit the number of users at the DOE scientific facilities which are an integral and vital part of the industrial, university, and government research enterprise in this country.

2. **What specific changes have occurred at your laboratory as a result of the implementation of the recommendations contained in the report of the Task Force on Alternative Futures for the Department of Energy Laboratories?**

Laboratory management, with the support of the Department of Energy, has made significant changes at Pacific Northwest National Laboratory that respond directly to the principle recommendations of the Galvin report. Many of these changes were in progress prior to the issuance of the report, but our efforts were lent added impetus both by the report and by the DOE's emphasis on implementation of the report's recommendations.

_ The Galvin report recommended strengthened mission focus at the national laboratories. We have established a clear mission focus around environmental science and technology. This mission focus, which is recognized and supported by DOE, is the foundation of our planning, and underlies the streamlined organizational structure that we implemented in April 1995.

_ The Galvin report asserted that improved management practices would allow reduction in administrative staff, elimination of unnecessary facilities, and reduction in overhead costs. In our 1995 staff reduction program we have disproportionately reduced our administrative staff count, thereby improving the ratio of scientists and engineers to support staff, and we are carrying out a facilities consolidation program including the vacating of obsolete or otherwise unsatisfactory facilities. In consequence, we have achieved reductions in the inflation-adjusted average hourly chargeout rate for our staff in FY94, and reductions in nominal dollars in both FY95 and FY96.

_ The Galvin report called for changes in the governance relationship between DOE and the national laboratories, with the Department focusing on specifying the outcomes to be achieved and the laboratories determining the "how". In partnership with the Department we have moved to an outcome oriented approach to performance assessment and implemented a self-assessment approach to operations management. As a result our current contract and performance evaluation agreement contains is based strictly on high-level scientific, engineering, and programmatic outcomes. All performance indicators are tied to well-defined results. In addition, the implementation of a rigorous self-assessment program has been incentivized by DOE, and is well under way. In our opinion this shift to outcome-based performance evaluation represents a major step forward in management practice.

_ The Galvin commission recommended use of best private sector management practices at the national laboratories. With the support of the Department we have implemented major reforms based on best private sector practice in such areas as procurement, time recording and reporting, computer workstation procurement, delivery, and maintenance, and electronic maintenance and distribution of policies, procedures, and operational manuals. These improvements have led to significant direct and indirect cost reduction. Further improvements may be anticipated as we continue our redesign of all major management systems in the laboratory.

3. What is the current number of FTEs at your laboratory, how does this compare with the FY95 level, and what are your outyear projections?

The following table contains FTE data for FY94 and FY95 and our FY 1996 - FY 2001 Institutional Plan projection for FY96-2001. Projections beyond FY97 should be viewed as highly approximate. We anticipate continued progress on improving the ratio of technical to support and administrative staff throughout that time period. However, technical staffing levels depend on budget and programmatic decisions made by Congress and the DOE.

	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01
FTEs	3911	3737	3192	3166	3165	3173	3239	3223
Δ vs 94		-4%	-18%	-19%	-19%	-19%	-17%	-18%

It is important to note that we began to reduce staffing levels in FY95, and FY94 is therefore the appropriate year to serve as the baseline.

4. From your perspective, what impact, if any, has the DOE Laboratory Operating Board had on the operation of your laboratory, or on DOE in general?

We believe that the October, 1995 report of the external members of the Laboratory

Operations Board has served to focus attention on the significant issues faced by DOE and the laboratories in making the transition in management practices and systems recommended by the Galvin report. As one example, the report was used as the basis for the agenda of the June DOE-wide summit on management principles and practices.

5. If the DOE FY 1997 budget is enacted as proposed, what would be the impact on your laboratory's scientific user facilities? Would you be able to continue the same level of operation as in FY 1996 or less? What additional funding, if any, would be required to maintain FY 1996 operating levels?

At Pacific Northwest National Laboratory we are in the final stages of construction of the Environmental Molecular Sciences Laboratory. This new scientific user facility is scheduled to begin operation in 1997, and initial operating funding is needed from the 1997 budget. The level of funding to be provided is under discussion with DOE's Office of Energy Research.

6. What is the current number of foreign scientists and engineers, by nationality, conducting research at your laboratory?

The Laboratory benefits from the services of 44 foreign nationals on our staff, the great majority of whom are permanent residents of the United States. Distribution by country of citizenship is as follows:

Barbados	1	
Canada	3	
Czech Republic	1	
England/UK	1	
France		1
Germany	2	
Ghana		1
Greece		1
Hong Kong	2	
India	8	
Iran	1	
Netherlands	3	
Poland		2
PR of China	11	
Russia		2
Sri Lanka	1	
Sweden	1	
Ukraine		1
Venezuela	1	

In addition to our permanent staff, the Laboratory has a fluctuating number of foreign nationals holding temporary appointments as either Postdoctoral Fellows or as visiting graduate and undergraduate students. Most of the student appointments are for the summer months; postdoctoral fellowships usually involve a full year. At present there are 102 such appointments of foreign nationals in the Laboratory, 46 of which are held by permanent residents of the United States. Countries of citizenship represented include Australia, Brazil (2), Canada (4), China (35), Croatia, the Czech republic, Denmark, England (9), Finland, Germany (3), Iceland, India (10), Ireland, Japan (4), Korea (2), Latvia, Poland (3), Russia (11), South Korea, Sri Lanka, Switzerland, Taiwan, the Netherlands (2), Vietnam (2), and Zimbabwe (2).

It is our experience that these visitors are highly productive, and make valuable contributions to our research programs.

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